Three Essays on Macroeconomics and International Macroeconomics

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Abstract

In the first chapter of my dissertation, I document three new stylized facts about sectoral comovement in the United States during the Great Recession and set up a multisector general equilibrium model to explain them. The first fact is that, unlike any other recessions after World War II, the output correlations between two sectors significantly increased during the Great Recession and reverted to the previous level afterward. Second, this increased comovement is positively correlated with the number of the input-output linkages between two sectors, reflecting the extensive margin of interconnectedness. Third, trade credit supply, as measured by the ratio of account receivables to the total value of outputs, collapsed during the Great Recession. Moreover, two sectors that experienced such a trade credit contraction had their correlation increasing more, on average, than two that did not. I then develop a multisector model with the endogenous supply of trade credit to explain these facts. The model shows that equilibrium trade credit reflects both the intermediate supplier's and client's bank lending conditions, and thus has asymmetric effects on sectoral outputs. If only the supplier (client) is financially constrained due to a bank lending shock, trade credit decreases (increases), partially offsetting the effect of the shock on the supplier's (client's) outputs. However, if both of them are financially constrained, trade credit flows toward the more constrained one, which further tightens financial constraint on the other. This mechanism propagates a bank lending shock and causes sectoral outputs to fall together, thereby explaining the increased comovement observed during the Great Recession.

In the second chapter, we analyze job switching and wage growth of young workers, separately considering the jobs experienced by workers before and after college completion. These two groups of jobs consist of very different occupational compositions. Workers with many jobs before college completion and with little or no job experiences before college

completion have similar subsequent wage paths. These facts can be interpreted that jobs before college completion contribute less to career building compared to the ones after college completion. If we disregard all jobs before college completion, the number of jobs that are experienced by workers before age 35 are about three jobs fewer than the total number of jobs.

The third chapter is to explain one phenomenons across countries during the Great Recession. It is that no robust relationship has been found between the decline in growth of countries during the Great Recession and their level of trade or financial integration. Here we confirm the absence of such a monotonic relationship, but document instead a strong discontinuous relationship. Countries whose level of economic integration (trade and finance) was above a certain cutoff saw a much larger drop in growth than less integrated countries, a finding that is robust to a wide variety of controls. We argue that standard models based on transmission of exogenous shocks across countries cannot explain these facts. Instead, we explain the evidence in the context of a multi-country model with business cycle panics that are endogenously coordinated across countries.

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Chapter 1

Sectoral Comovement during the Great Recession

1.1 Introduction

Sectors are interconnected via trading of intermediate inputs among their respective firms. The literature emphasizes that sectoral productivity shocks can have sizable effects on other sectors and even the aggregate economy through input-output linkages (e.g., see Long and Plosser (1983), Horvath (1998), Acemoglu et al. (2012)). Hornstein and Praschnik (1997), Shea (2002), and Foerster et al. (2011) argue that a large proportion of the aggregate volatility can be explained by the synergy of sectoral activities. Moreover, the payments for intermediate inputs are deferred. This deferral of payments, referred to as trade credit, financially interlocks firms at the top of the input-output linkage. Kiyotaki and Moore (1997) show that such financial interdependence can asymmetrically transmit an idiosyncratic financial shock from one firm to another. In this paper, I study how trading in intermediate inputs and issuance of trade credit jointly affect the comovement of sectoral outputs, measured as the pairwise correlation of output growth between two sectors, during the Great Recession.

I document three stylized facts about sectoral comovement during the Great Recession, examining quarterly outputs for 44 sectors in the United States. The first is that the distribution of pairwise correlations shifted significantly to the right during the recession and reverted to the pre–recession level in 2010.[1] Moreover, the rise in sectoral comovement is

[1] In a contemporaneous work, Li and Martin (2017) document a similar fact. My approach differs from

not a common feature for US recessions. With a subset of the quarterly data, I find that the distributions barely shifted in the 1990 or 2001 recessions. Using the annual data, I confirm the significant shift during the Great Recession, but I do not observe a similar shift during any other recession after World War II. Notably, the distribution shifted only slightly in the 1980 recession, even though it is comparable to the Great Recession in terms of the GDP drop.[2]

Second, I further explore the variation in pairwise correlations and find that it is positively correlated with the extensive margin of interconnectedness, which is defined by the number of input-output linkages between two sectors. All pairs of sectors are divided into three groups: the two-way trading group, in which two sectors are intermediate input providers and purchasers for each other; the one-way trading group, in which only one sector provides intermediates to the other; and the no trading group, in which no intermediates are traded between the sectors. In particular, the two–way trading group has a 0.17 higher average correlation than the one–way trading group, which has a 0.16 higher correlation on average than the no trading group. Moreover, compared to the pre–recession level, the average correlations during the Great Recession increased by 0.4, 0.27, and 0.13 for the two–way, one–way, and no trading groups, respectively. However, I find a positive but not statistically significant correlation between the pairwise correlations and the intensive margin of interconnectedness, which is measured as the proportion of one sector's intermediates shipped from the other sector over the total value of outputs.

Third, the intensity of trade credit provision (reception), defined as the ratio of account receivables (payables) to sales (operation cost plus the change in inventory), collapsed during the Great Recession. Due to data limitation, I classify both sectors as experiencing such a collapse if the intensity of trade credit provision of the upstream sector and the intensity of trade credit reception of the downstream sector both declined more than the median across sectors. The pairwise correlations for these pairs of sectors are higher on average than other pairs. Furthermore, their correlations increase more (0.19 on average) compared to

theirs in two ways. First, I calculate the correlation over eight quarters, while they use annual data from 2007 to 2009. They find higher correlations on average. Second, I incorporate detailed manufacturing sectors, while they only use durable and nondurable manufacturing sectors.

[2] Using EuropStat, I also find that during the Great Recession, major European countries, including Germany, France, and the United Kingdom, experienced a rise in sectoral comovement as in the United States. Moreover, during the European debt crisis era, sectoral comovement in Spain, Italy, and Greece significantly increased, while Germany, France, and the United Kingdom did not experience the similar phenomenon. See Appendix A.2 for more details.

the pre–recession level. This result remains the same after controlling for the trading flows in intermediate inputs, the bank lending shocks proposed by Chodorow-Reich (2014), and the sectoral characteristics.

To uncover the mechanism and reconcile these three facts, I develop a multisector model with an endogenous trade credit structure. In the model, firms are connected with each other via trading in intermediate inputs as well as financially through the trade credit chain. Similar to Bigio and La'O (2017), firms need to finance the advance payments for wages and part of intermediates through competitive banks, which require firms' shareholders to pledge a fraction of their outputs as collateral. This borrowing limit may place financial constraints on firms. To determine trade credit provision, all firms take their clients' responses in account and balance between the sales and loss of default.

In this model, sectoral productivity shocks can only be transmitted to the downstream, whereas bank lending shocks can be propagated to both the upstream and downstream sectors. In particular, due to the Cobb–Douglas form of preference and technology, a negative productivity shock to a sector can be transmitted to upstream sectors as the price of the upstream goods increases. The higher price reduces their clients' demand for intermediates, which further reduces their clients' outputs. Furthermore, a bank lending shock to one sector with a binding financial constraint can make it reduce the trade credit provision to its clients and demand more from its suppliers. Moreover, as in Kiyotaki and Moore (1997), adjusting trade credit has asymmetric effects on outputs in other sectors, contingent on the financial conditions of the suppliers and the clients. For example, if the client has sufficient amount of bank loan, it can use bank loan to replace trade credit. This leaves the client's output intact. Otherwise, the client become more financially constrained, which further distorts its production. In this case, the bank lending shock is transmitted to its clients. Analogously, the suppliers' responses also depends on their own financial conditions.

I calibrate the model to the US economy to examine the role of trade credit in propagating and amplifying shocks. First, I, both theoretically and empirically, show that merely the input-output linkage cannot account for the significant increase in pairwise correlations. Then, I use simulation and consider the case with the endogenous trade credit structure. The result shows that the density of pairwise correlations barely shifts during a recession, which, following the NBER, is defined as the real GDP declining by more than 1.5% for at least three consecutive periods. Even in a recession with GDP that drops 20% more than in the Great Recession, I still cannot observe the significant shift. After restricting to the recessions in which the financial constraints of firms in more than 75% sectors are binding for more than one period, I find the distribution on average shifts significantly during such recessions. Moreover, the pairwise correlations in the two-way trading group increase more on average than the ones in the one-way group. Also, the median intensity of trade credit declines by 8.1% during the recession, and such a decline in trade credit increases the pairwise correlations during the recession. In a counterfactual analysis, I fix the trade credit to the pre–recession level and find that the pairwise correlations decrease and the GDP drops by 2.3% on average instead of 2.8% in the case with the endogenous trade credit. This finding implies that trade credit amplifies shocks by 18%.

Trade credit is widely used in the United States. In 2016, the median ratios of accounts receivables and account payables relative to total assets are 6.6% and 6.0%, respectively, for big corporations with assets more than $250 million, while the ratios are 23.2% and 11.8%, respectively, for small firms with assets under $250 million.[3] Moreover, trade credit is the most important source for short–term finance. Account payables among big corporations in the United States are 8 times as much as a short–term bank loan, 11 times other short–term loans, and 25 times commercial paper; meanwhile, in small firms, account payables are 3 times as much as a short–term bank loan and 15 times other short-term loans. As emphasized in the statement made by Chrysler's CEO in the congressional testimony, no rescue fund 'would put sever pressure in having to pay CBD or cash upfront, and turn the whole financial equation up–side down'.

My finding accords with the empirical literature that explains that transmission of bad financial shocks through the trade credit chain depends on the financial status of both the supplier and client. On the one hand, firms with high liquid assets or access to bank credit increase their provisions of trade credit, especially when their clients find themselves hard to borrow (e.g., see Garcia-Appendini and Montoriol-Garriga (2013) and Love et al. (2007)). On the other hand, the delinquency or default on trade credit deteriorates suppliers' financial status, which may further lead them to delinquency or default on their own trade credit. Boissay and Gropp (2013) find that firms in France are more likely to default on their trade credit if they are facing default from their clients. Jacobson and von Schedvin (2016) document that in Sweden, annual bankruptcy risks for suppliers increase by 53% if some of their clients file bankruptcy.

The remainder of the paper is organized as follows. Section 2 discusses the three stylized

[3]My calculation from the QFR.

facts. Section 3 describes the model and analyzes the equilibrium. Section 4 concludes.

1.2 Three Stylized Facts

In this section, I begin by describing how to construct the measurement of sectoral comovement. Then, I provide three stylized facts about the sectoral comovement during the Great Recession. First, sectors significantly comoved during the Great Recession. Second, the increase in sectoral comovement is positively correlated with the extensive margin of the interconnectedness between two sectors. Third, the level of sectoral comovement is negatively correlated with the change in trade credit.

1.2.1 The Measure of Sectoral Comovement

The correlation of real GDP growth between two countries is widely used to study the business cycle comovement across countries; for example, see Frankel and Rose (1998) and Clark and van Wincoop (2001). Here, a similar measure, the pairwise correlation of output growth between two sectors, is applied to study the inter–sector comovement. First, I combine sectoral sales from the Quarterly Financial Report (QFR) with real gross industrial output, provided by the Bureau of Economic Analysis (BEA).[4] In total, the sample contains 44 sectors, covering all private sectors in the United States except Finance, Insurance, and Real Estate (FIRE).[5] Note that sales from the QFR are in the nominal term. To make it consistent with the real gross output provided by BEA, I deflate all series by the industrial price indexes in 2009 dollars and adjust for seasonality using the X-12-ARIMA seasonal adjustment program. Then I take the quarter–to–quarter growth rates of sectoral outputs and calculate the correlation of output growth between any pair of sectors as

$$\mathbf{corr}\left(\Delta y_i, \Delta y_j\right) = \frac{\sum_{t\in\mathcal{T}}\left(\Delta y_{it} - \mathbf{avg}\left(\Delta y_i\right)\right)\left(\Delta y_{jt} - \mathbf{avg}\left(\Delta y_j\right)\right)}{\left(\#\mathcal{T}-1\right)\mathbf{se}\left(\Delta y_i\right)\ \mathbf{se}\left(\Delta y_j\right)} \tag{1.1}$$

where subscripts i and j stand for two sectors, $\mathcal{T}$ is the time window of calculation, Δy_{it} is the quarter-to-quarter growth rate of output for sector i at time t, and **avg** and **se** are

[4] To test the consistence across two data sources, I compare the evolution of output growth rates for non-durable manufacture, durable manufacture, and wholesales sectors from two data sources respectively. The correlations between two sources are respectively 0.85, 0.7, and 0.76 from 2010Q1 to 2016Q4.

[5] Please refer to Table 28 in Appendix A.1.1 for the full list of sectors and their main characteristics.

respectively the sample mean and standard error of output growth rates over the time window $\mathcal{T}$. Throughout the analysis in the paper, I use eight consecutive quarters for the time window $\mathcal{T}$ unless otherwise stated. Note that given a certain time window, the correlation of pair (i, j) is the same as that of the pair (j, i), and hence, only one of them will be counted in my analysis.

1.2.2 Stylized Fact I

First, I examine the sectoral comovement during the Great Recession. Following Kahle and Stulz (2013), I choose 2007Q3–2009Q2 to cover the recession.[6] To compare, I also calculate the pairwise correlations before and after the recession, with 2005Q3–2007Q2 and 2009Q3–2011Q2 being chosen to respectively represent the periods before and after the recession. Figure 1 displays the kernel densities of 946 pairwise correlations for the three periods.[7] Before the recession, the density is hump-shaped with mean and median around 0.08, as shown in Table 1, and a near zero skewness suggests that it is almost symmetrical. During the recession, the density shifted significantly toward the right. The mean increases by 0.3, implying that the outputs of many sectors dropped together at that time. Moreover, the median rises even more, suggesting that a greater proportion of pairs move together than not. The density returned to the pre-crisis level soon after the recession. To test whether the densities before and after the recession are statistically different from the density during the recession, the Kolmogorov-Smirnov (KS) test is performed.[8] At the 0.1% significance level, the KS test rejects the null hypothesis that the density before (after) the recession is the same as the one during the recession. However, the standard deviation of the kernel density during the recession stays in line with its pre-crisis value. This result suggests that variation of sectoral comovement still exists. In Sections 1.2.3 and 1.2.4, I conduct several decompositions, based on the characteristics of sectors or pairs of sectors, and find that the trading in intermediates and the change in trade credit between two sectors are correlated with such high sectoral comovement during the Great Recession.

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[6] I alter the coverage and length of time windows. All results here are robust.

[7] I also calculate the weighted kernel density using the gross output share as weights. The shift is slightly more apparent.

[8] KS statistics are calculated as $D_{t\tau} = \sqrt{\frac{N_X}{2}} \max_{x \in X} |F_t(x) - F_\tau(x)|$, where t and τ stand for two different periods, N_X is the number of points associated with the kernel density, and $F_t(x)$ is the cumulative density function associated with period t. The critical values of KS statistics at 0.1%, 1%, and 5% significance level are respectively 0.0616, 0.0515 and 0.0430 in this case.

Is the high sectoral comovement a common feature for the US recessions? The answer is no. Because quarterly output data provided by BEA only start at 2005Q1 while all series from the QFR begin at 1987Q4, I use two methods to compare pairwise correlations during the Great Recession with those during other recessions. First, I focus only on manufacturing, wholesale, and retail sectors from the QFR. The sample covers two other recessions, specifically, the 1990 and 2001 recessions. In this case, the number of sectors drops to 20.[9] I adopt the same approach to calculate the pairwise correlations.[10] Figure 2 (3) shows the kernel densities of pairwise correlations before, during, and after the 1990 (2001) recession. Unlike the Great Recession, no rise in sectoral comovement is observed in the 1990 or 2001 recessions. Mean and median are unchanged during the 1990 recession and even decrease during the 2001 recession. For both recessions, the KS test cannot reject the null hypothesis that the kernel densities before and during the recession are the same at the 5% significance level. Moreover, the KS test rejects the null hypothesis, at the 0.1% significance level, that the kernel density during the 1990 (2001) recession is akin to the one during the Great Recession.

Second, the BEA provides the real gross outputs of 55 sectors since World War II, but at an annual frequency. I select a sample covering all private sectors except FIRE, and six recessions are studied, namely, the 1960, 1970, 1975, 1980, 1990, and Great Recessions. I use the Equation (1.1) to calculate the pairwise correlations over eight years, starting two years before each recession. Moreover, to compare the pairwise correlations during recessions, I also calculate the ones after the 1980 recession and before the Great Recession.[11] Figure 4 displays the kernel densities for all recessions and the controlling periods. Three observations can be made from this figure. First, the pairwise correlations calculated from the annual data are, in general, higher than the ones using the quarterly data. This result may be because some quarterly fluctuations can be averaged out in the annual data. Second, the density during the Great Recession still shifted significantly toward the right, compared with the one

[9]Since 2000Q4, the QFR adds disaggregate information for some sectors. For example, *Electrical and Electronic Equipment* is separately reported as three individual sectors since 2000Q4, namely *Computer and Peripheral Equipment*, *Communications Equipment*, and *All Other Electronic Products*. I use the cross-walk between SIC and NAICS to aggregate the sectors after to the ones before 2000Q4. In this case, the classification is consistent when we calculate the kernel densities throughout the 2001 recession.

[10]1989Q1–1990Q4, 1990Q1–1991Q4 and 1992Q1–1993Q4 are chosen to represent the before, during and the after the 1990 recession. 1998Q4–2000Q3, 2000Q4–2002Q3, and 2002Q4–2004Q3 are chosen for the 2001 recession.

[11]The period starting points are respectively 1957, 1967,1972,1978,1988,and 2005 for the 1960, 1970, 1975, 1980, and 2008 recessions, and 1983 for the post–1980 and 2000 for pre–2008 recession.

before. This observation is consistent with the one shown in Figure 1. Third, no significant shift is observed during other recessions. For example, the 1980 recession is the only one that is relatively comparable to the Great Recession in terms of GDP drop.[12] Surprisingly, the density during the 1980 recession shifted toward the right only slightly, if at all, compared to the density after the recession.

In Appendix A.2, I study European countries' sectoral comovement during the Great Recession and the European Debt Crisis. I find that all major countries in Europe, including Germany, France, the United Kingdom, Italy, Spain, and Portugal, experienced similar sectoral comovement as in the United States. This finding provides additional evidence to business cycle synchronization across countries during the 2008 Great Recession as documented in Bacchetta and van Wincoop (2016). Moreover, during the European Debt Crisis, Spain, Italy, and Greece all experienced the high sectoral comovement. However, Germany, France, and the United Kingdom did not have a similar increase in sectoral comovement over the same period. This finding suggests that the financial crisis differs from other recessions and has a significant implication on the sectoral comovement.

1.2.3 Stylized Fact II

Next, I examine the role of trading in intermediate inputs in the increase of the sectoral comovement during the Great Recession. To identify the intermediate trading relationship between two sectors, I aggregate the 2007 US Industry Input-Output (IO) table with 385 industries into one with 45 private sectors, including FIRE. I calculate the input-output matrix, each element of which is the share of intermediate inputs from the upstream to the downstream sector over the total intermediates used by the downstream one. If such a share is too low, namely 0.1%, I set it equal to 0.[13] Then all pairs are categorized into three groups, according to the extent of their interconnectedness. In particular, two sectors are classified into the two-way trading group if they are both intermediate provider and purchaser to each other, into the one-way trading group if only one sector purchases intermediate inputs from the other but not vice versa, and no trading group if no intermediate input is traded between them. Each group has 381, 410, and 155 pairs, respectively.

[12] According to FRED economic data, in 1982, the U.S. GDP dropped 1.9% with the deepest drop at 6.5% in 1982Q1, whereas GDP contracted 2.7% in 2008 with the largest contraction at 8.2% in 2008Q4.

[13] I also try to relax such restraints and other restraints, namely 0.05% and 0.25%. All results here are robust.

Figure 5 displays the comparison of kernel densities during the Great Recession across three groups. The extents of interconnectedness between two sectors are positively correlated with the sectoral comovement during the recession. In particular, the two-way trading group has 0.17 higher average correlation than the one-way group and 0.31 higher than the no trading group, as Table 2 shows. This outcome implies that the pairs with two-way interconnection mainly drive the sectoral comovement during the Great Recession, and it also indicates that a sector-specific shock can be transmitted via the production network. Also, medians follow the same order, and the difference is slightly larger across groups. High skewness in the two-way group suggests that many pairs in this group move at the same pace during the Great Recession. The KS statistics are 0.16 comparing the two-way with the one-way trading group, 0.23 comparing the two-way with the no trading group, and 0.09 comparing the one-way with no-trading group. All tests reject the null hypothesis that two densities are the same at the 0.1% significance level.

Fixing the same categorization before and after the Great Recession, I take pairwise correlations and calculate kernel densities for each group. The densities before and after the Great Recession, however, have very similar statistical moments across three groups, as shown in Table 2. Figures 21 and 22 in Appendix A.5 display the kernel densities of three groups before and after the Great Recession, respectively, and overlap one another. Moreover, a mean difference test is conducted to determine whether the increase of pairwise correlations from the pre–crisis level differs across groups. The average increases in the pairwise correlations are 0.40, 0.27, and 0.13 for the two-way, one-way, and no trading groups, respectively. All mean differences are statistically significant at the 0.1% significance level. These findings suggest that the higher margin of interconnectedness also corresponds to a larger increase in sectoral comovement.

In Appendix A.3, I further categorize sectors based on whether the products from a sector are mainly used as consumption goods or intermediate inputs. The results are consistent with stylized fact II. The group in which sectors mainly provide their goods as intermediate inputs has a higher pairwise correlation on average during the Great Recession than the counterpart. This finding shows the relevance of input-output linkage among sectors with the sectoral comovement. Moreover, I compare the pairwise correlations of manufacturing with those of service sectors. The difference of two kernel densities is not statistically significant because some service sectors also serve as important intermediate providers.

1.2.4 Stylized Fact III

In this subsection, I examine how the change in trade credit during the Great Recession is correlated with the sectoral comovement. First, I introduce trade credit and its importance as a vehicle of firms' short-term finance. Second, I show that two sectors that experienced a decline in trade credit during the Great Recession are more correlated on average than two that did not. Third, I show that the increase in correlation remains the same, conditional on the change of intermediate trade flows, the bank lending shocks, and other sectoral characteristics.

The Usage of Trade Credit during the Great Recession

In addition to trading in intermediate inputs, firms simultaneously provide trade credit to their clients and receive the same from their suppliers in the form of deferred payments for goods or services output. Suppliers' claims against clients are recorded as account receivables in suppliers' balance sheets, while liabilities of clients to suppliers are recorded as clients' account payables. Trade credit is ubiquitous in and beyond the US markets. In 2016, the median ratios of account receivables and account payables relative to total assets are 6.6% and 6.0%, respectively, for big corporations with assets more than $250 million, while the ratios are 23.2% and 11.8%, respectively, for small firms with assets under $250 million.[14] Worldscope, the worldwide surveys conducted by the World Bank, find that firms typically finance about 20% of their working capital with trade credit, and firms in 60% countries use trade credit more than bank credit for short–term financing. Moreover, trade credit is the most important source of short–term finance. In the United States, account payables among big corporations are 8 times as much as a short–term bank loan, 11 times other short–term loans, and 25 times commercial paper, while in small firms, they are 3 times as much as a short-term bank loan and 15 times other short–term loans.

To examine the evolution of trade credit usage, I use the US public firms' data from COMPUSTAT to calculate the intensity of trade credit provision and reception. I take the ratio of account receivables to total value of sales as the intensity of trade credit provision and the ratio of account payables to the sum of total operational costs and change in the inventory as the intensity of trade credit reception.[15] I then adjust for seasonality of two

[14] Author's calculation from the QFR.

[15] I select nonfinancial firms, following Kahle and Stulz (2013). See Appendix A.1.2 for details.

series for each firm and take the median value across firms in each quarter. Figure 6 displays the evolution of two ratios from 1980Q3 to 2016Q3. Both ratios fluctuate modestly over time, even throughout the 1990 and 2001 recession. In the 1980 recession, they increased moderately. During the Great Recession, they went up at the beginning and plummeted by roughly 10% starting in 2008Q3. This pattern indicates that in addition to output, more firms then either requested more downpayment for new intermediate orders or wrote off the existing trade credit. Love et al. (2007) study trade credit usage both in Mexico during the 1994 peso devaluation and in five East Asian countries during the 1997 Asian flu. They also find that the trade credit provision slightly increased at the beginning of the crisis and dropped largely afterward.

Sectoral Comovement vs the Change in Trade Credit Usage

From here on, I restrict my analysis to manufacturing, wholesale, and retail sectors from the QFR because of data limitation. For each sector, I calculate the quarterly intensities of trade credit provision and reception as in Section 1.2.4 and then adjust for seasonality. For each series, I take the median value over 2005Q3–2007Q2 and over 2008Q3–2009Q2 to respectively represent the intensities of trade credit provision (reception) before and during the recession. Then, I calculate the percentage change over two periods to measure the change in trade credit provision (reception) relative to the value of sales (operational cost). Note that these measures only estimate the change of gross trade credit provision to all clients of a firm or reception from its suppliers. Therefore, a pair is considered as experiencing trade credit decline during the Great Recession if both the intensity of the upstream sector's trade credit provision and the intensity of the downstream sector's trade credit reception declined by more than the median value.[16] Otherwise, the pair is categorized into the control group. Define

$$\mathbf{D}^{tc} = \mathbf{1}\left(\Delta\frac{AR_i}{S_i} < \Delta^m\frac{AR}{S} \;\; and \;\; \Delta\frac{AP_j}{OC_j} < \Delta^m\frac{AP}{OC}\right) \tag{1.2}$$

where $\Delta\frac{AR}{S}$ is the percentage change in account receivables relative to output, $\Delta\frac{AP}{OC}$ is the percentage change in account payables relative to the sum of operational costs and change in the inventories, and $\Delta^m\frac{AR}{S}$ and $\Delta^m\frac{AP}{OC}$ are respectively the median values of $\Delta\frac{AR}{S}$ and $\Delta\frac{AP}{OC}$. Figure 7 exhibits the kernel densities of the pairwise correlations during the Great

[16] 6.3% and 6% are respectively the median drops of the intensity of trade credit provision and reception across sectors.

Recession for two groups. The figure shows the relevance of the change in trade credit usage with the sectoral comovement. Specifically, two sectors that experienced a decline in trade credit have an average correlation that is 0.21 higher than two that did not, as Table 3 shows. The similarity of two densities is rejected by the KS test at the 0.1% significance level. In Appendix A.5, I show that the kernel densities of two groups are more or less the same before and after the Great Recession.

Robustness Check

The positive correlation between the decline in the intensity of credit trade and the rise in sectoral comovement can be driven by a change in the intermediate trading flows between two sectors or their external borrowing conditions. In particular, outputs in many sectors collapsed during the Great Recession. Such a collapse may sharply reduce demands for their intermediate inputs and further cause outputs of their upstream sector to contract as well. Thus two sectors would move together. Meanwhile, if the intensity of trade credit usage between two sectors responds convexly to the change in trading of intermediates, a drop in the latter can cause the former to shrink more. In this case, both the decline in the intensity of trade credit and the rise in sectoral comovement are caused by the collapse in intermediate trading. Moreover, the literature has documented the credit crunch from banks during the Great Recession; for example, see Ivashina and Scharfsteinb (2010), Brunnermeier (2009), and Shleifer and Vishny (2010). This bank lending shock can generate contractions across various types of firms' activities, including cutting off production and limiting trade credit issuance. In this case, the positive correlation between the decline in credit trade and the increase in sectoral comovement can be caused by the bank lending shocks.

In this subsection, I conduct mean difference tests to study whether the positive correlation observed in Section 1.2.4 still exists, even conditional on intermediate trading flows and bank lending during the Great Recession. Because no comprehensive dataset is available to measure the change in intermediate trading flows between two sectors, I define

$$\Delta TF_{ij} = \gamma_{ij}\ Output\_Share_j\ \Delta y_j \tag{1.3}$$

where γ_{ij} is element (i,j) of the inverse Leontief matrix, $Output\_Share_j$ is the output share of sector j over the total economy in 2007, and Δy_j is the percentage change in sector j's output from 2007 to 2008. γ_{ij} incorporates both direct and indirect trading in intermediate inputs from sector i to j.[17] Output shares are used to make the change in output directly comparable across sectors. Thus ΔTF_{ij} measures the percentage change in sector i's output, corresponding to the change in sector j's output through direct and indirect intermediate trading between the two sectors.

For bank lending shock, I adopt the measure proposed by Chodorow-Reich (2014) to assess the difficulty of borrowing from the syndicated loan market during the Great Recession relative to its pre–recession level.[18] First, define $L_{b,-f}$ as the quantity of loans made by bank b to all borrowers except firm f during the Great Recession relative to its pre–recession level as

$$L_{b,-f} = \frac{2\sum_{k\neq f,l} \alpha_{b,k,l,crisis}}{\sum_{k\neq f,l} \alpha_{b,k,l,before}} \tag{1.4}$$

where $\alpha_{b,k,l,t}$ is the share of the syndicated loan l from bank b to firm k over period t.[19] The 'before' period covers October 2005 through June 2007 except from July to September 2006, while the period of October 2008 through June 2009 are used for 'crisis'. $L_{b,-f}$ measures the difficulty of borrowing from a bank b, in terms of extensive margin, exogenously to a firm f.[20] I define the measure of difficulty of borrowing for each firm as

$$BL\_Shock_f = \sum_{b\in\mathcal{S}_f} \alpha_{b,f,last,before} L_{b,-f}$$

where $\mathcal{S}_f$ is the set of banks lending to firm f and $\alpha_{b,f,last,before}$ is the lending share of the last loan before the Great Recession. Notably, BL_Shock_f is the weighted average of the difficulty of borrowing in the syndicated loan market across all lenders. Last, we take the median value across firms for each sector as the sectoral bank lending shock, denoted as BL_Shock_i.[21]

[17] I also consider only including the direct linkage using input–output matrix. All results here are robust.

[18] Note that borrowers in the syndicated loan market can be unlisted or unrated firms. This wide coverage can be helpful in understanding the external borrowing condition, compared to the case in which listed firms are the sole focus

[19] Roughly a third of all loans have shares available among lenders. For the rest, we follow Chodorow-Reich (2014) and Ivashina and Scharfsteinb (2010). First, according to the number of arranger and follower lenders, we make them into 16 groups based on population. Then we use the available shares to calculate the average share of arranger and lender in each group and assign the share to each lender accordingly.

[20] I also use the size of loans relative to firms' output instead of the indicator of borrowing. The results here are robust. However, many loans are in the form of the credit line, and the information about withdrawing is not available. Thus using the relative size of loan may underestimate the difficulty of borrowing condition for firms during the Great Recession.

[21] I also use 25 and 75 percentile values. I only find robust results using 25 percentile values.

Next, I divide all pairs into four categories, based on the values of change in their intermediate trading and the bank lending shocks. In particular, a pair is categorized into the group experiencing a large decline in trading flows if trading in intermediate inputs between them is smaller than the median across all pairs. Also, a pair is considered as experiencing severe difficulty in borrowing from banks if both sectors receive a bank lending shock larger than the median.[22] Then, I define

$$\mathbf{D}_{ij}^{tf} = \mathbf{1}\big(\Delta TF_{ij} < \Delta^m TF\big) \tag{1.5}$$

$$\mathbf{D}_{ij}^{bl} = \mathbf{1}\big(BL\_Shock_i \leq BL\_Shock^m \ and \ BL\_Shock_j \leq BL\_Shock^m\big) \tag{1.6}$$

where $\Delta^m TF$ stands for the median value of ΔTF across all pairs and BL_Shock^m is the median of BL_Shock across all sectors.

Within each category, I perform the mean difference test and examine whether two sectors experiencing the trade credit collapse during the Great Recession still have a higher correlation on average. Table 4 reports the statistics from the tests. Several observations can be drawn. First, the pairwise correlation in the trade–credit–decline group increases more than among their counterparts across all categories. Even for the pairs in which both sectors do not significantly contract the intermediate trading or have difficulty borrowing from the banks, their pairwise correlations increase significantly during the recession if the trade credit between them collapse. Surprisingly, the difference of the increase in the fourth category is almost as large as that in the first category, given that only a fifth of them experience collapse in trade credit in the fourth category. Second, the increases are statistically significant except in the third category. Third, the trading in intermediate inputs and the bank lending condition are indeed relevant to the pairwise correlations. Two sectors that experience a large decline in intermediate trading or had severe trouble borrowing from the banks have a higher average correlation than two that do not. Also, they are more likely to experience a decline in trade credit. Moreover, in Appendix A.4, I conduct a regression to examine how much the increase in pairwise correlations is associated with the indicator of trade–credit–decline. The results show that experiencing the decline in trade credit during Great Recession is associated with an increase of 0.19 in pairwise correlation on average, and the results are robust even after controlling for various of sectoral characteristics. Furthermore, in the online Appendix, I show that the average correlations during the Great

[22] The median value of TF_{ij} is -8.55×10^{-6}. The median of BL_Shock is 0.55.

Recession are, in terms of statistics, significantly higher for two sectors that experience the decline in trade credit, and the results are robust across four categories. Also, I find that the average correlation between two trade–credit groups is not, in terms of statistics, significantly different before or after the Great Recession across four categories.

1.3 Model

In this section, I develop a multisector model to uncover the mechanism of the rise in sectoral comovement during the Great Recession. First, I describe the environment of the multisector model incorporating an endogenous trade credit structure and discuss its solution. Then, I discuss the limitation of the model without the financial constraint to generate sectoral comovement. Next, I simulate the model with 15 sectors and show that this model can replicate the three stylized facts observed in Section 1.2. Last, I conduct a counterfactual analysis to highlight the role of trade credit in amplifying shocks during the financial recession.

1.3.1 Environment

Firms

Suppose that the economy has N sectors, each of which has a continuum of firms on the interval $[0, 1]$. Each firm hires labor and purchases intermediate inputs from other firms to produce consumption goods for household and intermediate inputs for other firms. Assume that each firm purchases (provides) intermediates from (to) at most one firm in each sector. Refer to firms providing (receiving) intermediates as suppliers (clients). Sectors are interconnected with each other via this vertical production network. Suppose that the production of firm $k \in [0, 1]$ in sector i takes Cobb-Douglas form:

$$y_i(k) = z_i \xi_i(k) \prod_{j=1}^{N} m_{ji}^{\omega_{ji}} l_i^{\alpha_i} \tag{1.7}$$

where z_i and $\xi_i(k)$ are respectively the sector and firm–level productivities, m_{ji} is the intermediate inputs delivered from firms in sector j, ω_{ji} is the share of expenditure on intermediate inputs from sector j over the gross value of output, l_i is the employed labor, and α_i is the labor share.[23] Note that $\omega_{ji} = 0$ means that firms in sector i do not purchase intermediate inputs from any firms in sector j. Suppose the firm–specific productivity ξ_i is Bernoulli distributed:

$$\xi_i = \begin{cases} \xi_i^h & with \quad prob\, 1-\kappa \\ \xi_i^l & with \quad prob\, \kappa \end{cases}$$

Without the loss of generality, assume $(1-\kappa)\xi_i^h + \kappa\xi_i^l = 1$ for $\forall i$. Let y_i be the sectoral output, which is aggregated across all firms in sector i as $y_i = \int_0^1 y_i(k)\mathbf{d}k$. Also, by law of large number, y_i can be interpreted as the expected output as $y_i = \mathbf{E}_i\left[y_i(k)\right]$, where $\mathbf{E}_i\left[\cdot\right]$ is the expectation operator of the firm–specific productivity for firms in sector i. Moreover, I assume that for any sector i, the sectoral productivity follows an $AR(1)$ process as

$$\log \mathbf{z}_{i,t+1} = \rho_i \log \mathbf{z}_{it} + \epsilon_{i,t+1} \tag{1.8}$$

where the vector of $\{\epsilon_{it}\}$, $\epsilon_t = [\epsilon_{1t}, \ldots, \epsilon_{Nt}]'$, is serially independent, following a joint normal distribution $\mathcal{N}\Big(\mathbf{0}, \Sigma\Big)$. Here, Σ is a symmetric and positive definite matrix.

Each period is split into two stages. At the first stage, only sectoral productivities are realized, and hence firms are still uncertain about their productions because of the unknown firm-level productivities. Nevertheless, they need to order intermediate inputs and employ workers in order to produce later. In this case, they make the decision based on the expectation of the firm-specific productivities. Also, due to the uncertainty, firms' ability to make payments for labor and intermediate inputs is at risk. Therefore, workers and suppliers demand to be paid in advance. I assume that workers have strong bargaining power over firms and they are consequently compensated upfront at the full amount. The payments for intermediate inputs are divided into two parts: cash before delivery (CBD) and trade credit. The former is due to the first stage, while the latter is deferred until the next stage when their clients realize their revenue. The division is endogenously decided by suppliers. Suppose that no profits can be stored over periods. To fulfill the upfront payment for workers and suppliers, firms firstly exhaust the CBD received from their clients and then borrow from

[23] One can think that in this mode, firms use capital as well. Just the capital is always set to 1.

banks if there is a shortage. Therefore, the amount of borrowing for firms in sector i is:

$$b_i = \max\left\{\underbrace{wl_i}_{wage} + \underbrace{\sum_{j=1}^{N}(1-d_{ji})\,p_j m_{ji}}_{CBD\ to\ be\ paid} - \underbrace{\sum_{j=1}^{N}(1-d_{ij})\,p_i m_{ij}}_{CBD\ received}, 0\right\} \tag{1.9}$$

where w is the wage, p_j is the price of intermediate inputs from sector j, and d is the proportion of trade credit over the total intermediate payment. For example, the total payment for intermediate inputs delivered from firms in sector j to firms in sector i, $p_j m_{ji}$, is divided into two parts: $(1-d_{ji})p_j m_{ji}$ as CBD and $d_{ji}p_j m_{ji}$ as trade credit.

At the second stage, firms realize their specific productivities. All goods are produced and delivered. As discussed later, due to the agreement between shareholders and banks, bank loans is guaranteed to be repaid. However, because trade credit is not collateralized nor endorsed by shareholders, clients can choose to default on trade credit if they do not have enough revenue. If suppliers find out that their clients default on trade credit when they generate enough revenue to pay back, suppliers will punish them by not providing intermediate inputs such that clients will not be able to produce in the future. To ensure the truth telling, at the end of each period, both suppliers and clients verify information provided by counterparts. Also, this verification process is costly when the intensity of trade credit in equilibrium deviates away from the neutral level, $\bar{d}$, which is the intensity without any shocks. Assume that the cost is $\varphi_i(d_{ji}-\bar{d}_j)^2 p_j$ per unit of intermediate inputs. Here φ is the parameter governing the size of such verification cost. Moreover, I assume that suppliers bear this cost. Assumption 1 lays out the conditions that $\left\{\xi_i^l\right\}$ should satisfy.

Assumption 1. *Assume that for each i, ξ_i^l is sufficiently low such that firms with low productivities are not able to pay back trade credit and ξ_i^l is sufficiently high such that they can produce enough to produce enough for their clients.*

The first part of Assumption 1 rule out the meaningless case that even firms with low productivities can generate enough revenue to repay trade credit. The second part ensures that these firms still can produce enough and deliver intermediate inputs as ordered. In this case, all firms make the same revenue from the intermediate–input market, while firms with high productivities sell more in the consumption–good market. Note that firms have a probability κ to draw such low productivity. By the law of large numbers, κ fraction of them in each sector choose to default.

Banks

Suppose many competitive banks exogenously exist in the economy and they have deep pockets and offer loans to firms. Also, suppose they are risk–averse. Because some firms will have low productivities and thus may not generate enough revenue, banks concern about the firms' ability to repay so that they are reluctant to lend. To ensure banks, firms' shareholders make an agreement with banks and promise to take over the debt responsibilities when firms cannot. To enforce such agreement, banks ask shareholders to pledge some fraction of the expected revenue from the consumption-good market as collateral. This is because by the time when banks lend to firms, banks cannot tell which firms will have low productivities so that they ask for the access to liquidate outputs in the consumption-good market. Also, banks do not take trade credit as collateral because of its potential default risk. Denote the proportion of revenue that can be pledged as collateral is e_i for firms in sector i. Loans from banks are in the form of credit line that gives firms permissions to access loans up to a limit, namely $e_i p_i c_i$. In other words, firms in sector i are subject to the financial constraint as

$$b_i \leq e_i p_i c_i \quad with \quad e_i = \bar{e}_i \epsilon_i^e \tag{1.10}$$

where ϵ_i^e follows a log-normal distribution $\log \mathcal{N}(0, \sigma_i^e)$.

Note that two sources of credit, namely bank and trade credit, coexist in my model. They differ in two ways. First, trade credit is just the deferral of payments, and at least some firms need bank credit to pay their workers and CBD. Thus, trade credit is the vehicle for redistributing bank loans. Second, bank loans are collateralized by income of shareholders, and thus they will always be repaid. However, trade credit is determined by suppliers. It is not secured, and clients default if they cannot generate enough revenue.

Output is produced under conditions of perfect competition. At the first stage, before firm-specific productivities are realized, all firms in the same sectorare *ex ante* the same so that they make the same decisions. In this case, taking the prices for output and inputs and the intensities of trade credit issued by all suppliers as given, firms hire labor, order intermediate inputs, and determine the intensity of trade credit providing to their clients to maximize the expected profits:

$$\max_{m_{ji},l_i,d_{ij}} \quad p_i z_i \prod_{j=1}^{N} m_{ji}^{\omega_{ji}} l_i^{\alpha_i} - \sum_{j=1}^{N} \kappa d_{ij} p_i m_{ij} - w l_i - \sum_{j=1}^{N} \left(1-\kappa d_{ji}\right) p_j m_{ji} - \varphi_i \sum_{j=1}^{N} (d_{ij}-\bar{d}_i)^2 p_i m_{ij} \tag{1.11}$$

$$s.t. \qquad w l_i + \sum_{j=1}^{N} \left(1-d_{ji}\right) p_j m_{ji} \leq e_i p_i c_i + \sum_{j=1}^{N} \left(1-d_{ij}\right) p_i m_{ij}$$

where the first two terms stands are the expected revenue, the fourth term is the expected cost of purchasing intermediate inputs, and the constraint is a result of combination of Equation (1.9) with (1.10). Here, the loss or gain of default on trade credit is taken into account. This problem can be broken into two steps. In the first step, the firm chooses the amount of labor l_i and intermediate inputs $\{m_{ji}\}_j$ to use, given the wage w, prices of the intermediate inputs $\{p_j\}_j$, and the intensities of trade credit received from their suppliers $\{d_{ji}\}_j$. Suppose that μ_i is the Lagrange multiplier for the financial constraint of firms in sector i. The solution to the first step is presented in the following lemma.

Lemma 1. *Given a vector of prices* $\left\{\{p_j\}_j, w\right\}$ *and the intensities of trade credit receptions from other sectors* $\{d_{ji}\}_j$*, the optimal conditions of firms in sector* i *satisfy the following conditions:*

$$w l_i = \alpha_i \theta_i^l p_i y_i, \quad with \;\; \theta_i^l = \frac{1}{1+\mu_i} \tag{1.12}$$

$$p_j m_{ji} = \omega_{ji} \theta_{ji}^m p_i y_i, \quad with \;\; \theta_{ji}^m = \frac{1}{1-\kappa d_{ji} + (1-d_{ji})\mu_i} \tag{1.13}$$

Proof: see Appendix A.6.

Lemma 1 implies the expenditure on labor and intermediate inputs are respectively proportional to the total value of expected output. This is a classical result of Cobb-Douglas technology. Moreover, if the financial constraints are not binding, the proportions are equal to labor and intermediate inputs shares, i.e. α and ω. If firms are financially constrained, distortions on labor and intermediate input are induced and consequently they cannot reach their profit-maximizing production.

Moreover, θ_{ji}^m is increasing in d_{ji}. It implies that the more trade credit suppliers in sector j provide, the effectively more clients in sector i purchase intermediate inputs from sector j. In the second step, when firms determine trade credit supply, they take this fact into account. Given the gross value of output for their clients in sector j, i.e. $p_j y_j$, firms in sector i choose the intensity of trade credit to solve

$$\max_{d_{ij}} \quad \left(1 - \kappa d_{ij} - \varphi_i (d_{ij} - \bar{d}_i)^2\right) p_i m_{ij}$$

$$s.t. \qquad p_i m_{ij} = \frac{\omega_{ij}}{1 - \kappa d_{ij} + (1 - d_{ij})\mu_j} p_j y_j$$

$$w l_i + \sum_{j=1}^{N} (1 - d_{ji})\, p_j m_{ji} \leq e_i p_i c_i + \sum_{j=1}^{N} (1 - d_{ij})\, p_i m_{ij}$$

Issuing more trade credit has a trade–off: increasing the sales of intermediate inputs while enhancing the loss in the case of default. Lemma 2 describes the solution to the problem.

Lemma 2. *Assume that $\kappa + \bar{d}_i < 1$, for $\forall i$. Given the price of good i and the gross value of output for their clients in sector j, the optimal condition to determine the intensity of trade credit is*

$$d_{ij} = \frac{1 + \mu_j}{\kappa + \mu_j} - \sqrt{\left(\frac{1 + \mu_j}{\kappa + \mu_j} - \bar{d}_i\right)^2 + \frac{(1 - \kappa)(\mu_i - \mu_j)}{\varphi_i (\kappa + \mu_j)}} \tag{1.14}$$

Proof: see Appendix A.6.

Lemma 2 implies that the intensity of trade credit is only adjusted to the financial conditions of both supplier and client. Proposition 1 describes how it is adjusted.

Proposition 1. *Given the Lagrange multipliers for both the supplier i's and client j's financial constraints, μ_i and μ_j respectively, we have*

- *if $\mu_i = \mu_j$, $d_{ij} = \bar{d}_i$;*
- *if $\mu_i > \mu_j$, $d_{ij} < \bar{d}_i$;*
- *if $\mu_i < \mu_j$, $d_{ij} > \bar{d}_i$;*

Moreover, if $\kappa + \varphi_i \left(1 - \bar{d}_i\right)^2 < 1$ for $\forall i$, then we have

$$\frac{\partial d_{ij}}{\partial \mu_i} < 0, \quad \text{and} \quad \frac{\partial d_{ij}}{\partial \mu_j} > 0$$

Proof: see Appendix A.6.

The first part of Proposition 1 suggests that the intensity of trade credit is determined by the relative financial conditions of both suppliers and clients. If suppliers have relatively worse financial conditions, i.e. μ_i is larger than μ_j, then less trade credit is extended, compared to the natural level. Similarly, if clients have relatively worse financial conditions, then the suppliers extend more trade credit than the natural level. The second part of Proposition 1 implies that the intensity of trade credit is decreasing as the suppliers' financial conditions deteriorate, while increasing as the clients become more financially constrained.

Proposition 2. *Assume that $\kappa < 2\varphi_i\left(1-\bar{d}_i\right)$ for $\forall i$. The distortions on labor and intermediate inputs satisfy*

$$\frac{\partial \theta_i^l}{\partial \mu_i} < 0, \quad \frac{\partial \theta_{ji}^m}{\partial \mu_j} < 0, \quad and \quad \frac{\partial \theta_{ji}^m}{\partial \mu_i} \begin{cases} < 0 & if \;\; \mu_i < \frac{2\varphi_j\left(1-\kappa\bar{d}_j\right)\left(1-\bar{d}_j\right)+(1-\kappa)(\mu_j-\kappa)}{1-\kappa-\varphi_j\left(1-\bar{d}_j\right)^2} \\ \geq 0 & otherwise \end{cases}$$

Proof: see Appendix A.6.

Proposition 2 implies that as the financial constraint becomes binding, labor and intermediate inputs will be distorted. Moreover, if one supplier becomes financially constrained, the incentive for the supplier to extend trade credit reduces so that the clients will spend smaller proportion of their cost on goods provided by this supplier.

Households and Market Clearing Conditions

Suppose a representative household exists in the economy with utility $\mathbf{U}(c,l) = \log c - \eta l$, where c is the consumption bundle, l is hours worked, and the parameter η governs the disutility from working. The total expenditure must be weakly less than the household's labor income plus net profits and transfer from firms. Given the prices and wage, the household's objective is to choose a consumption bundle and labor to maximize her utility subject to her budget constraint as

$$\max_{c_t, l_t} \mathbf{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \Big(\log c_t - \eta l_t \Big) \right] \tag{1.15}$$

$$s.t. \qquad p_t c_t \leq w_t l_t + \pi_t + T_t$$

where p is the price index, π is the total profit generated by all firms, and T is the total verification costs paid by firms. The first order conditions yield

$$\eta c = \frac{w}{p} \tag{1.16}$$

Moreover, the consumption bundle is defined as the composition of goods from all sectors as

$$c = \prod_{i=1}^{N} \left(\frac{c_i}{\nu_i}\right)^{\nu_i} \tag{1.17}$$

and the price index is defined as

$$p = \left(\prod_{i=1}^{N} p_i\right)^{\nu_i} \tag{1.18}$$

where ν_i is the share of the household's expenditure on sector i's goods and $\sum_{i=1}^{N} \nu_i = 1$. Moreover, a household's demand for goods in any sector i is given as

$$c_i = \nu_i \frac{p}{p_i} c \tag{1.19}$$

All products in any sector are served for two purposes: intermediate inputs and consumption goods. Thus output in any sector should be equal to the summation of consumption by household and intermediate inputs shipping to every sectors; that is, for any sector $i \in \{1, \ldots, N\}$,

$$y_i = c_i + \sum_{j=1}^{N} m_{ij} \tag{1.20}$$

Finally, labor supply is equal to labor demand across firms in all sectors as

$$l = \sum_{i=1}^{N} l_i \tag{1.21}$$

Definition of Equilibrium

Now I define the competitive equilibrium in my model as

Definition 1. *A* ***competitive equilibrium*** *is defined as commodity prices* $\{p_i\}_i$ *and wage* w*, sectoral output* $\{y_i\}_i$*, consumption goods* $\{c_i\}_i$*, intermediate inputs* $\{m_{ji}\}_{j,i}$*, labor allo-*

cations $\{l_i\}_i$, *and the intensities of trade credit provision* $\{d_{ji}\}_{j,i}$, *such that*

1. *Given a vector of prices* $\left\{\{p_j\}_j, w\right\}$ *and the intensities of trade credit receptions from other sectors* $\{d_{ji}\}_j$, *firms in any sector* i *choose intermediate inputs* $\{m_{ji}\}_{j,i}$, *labor* l_i, *and the intensities of trade credit provision* $\{d_{ij}\}_j$ *to maximize the expected profit as in (1.11);*

2. *Given* $\{p_i\}_i$ *and* w, *the representative household chooses consumption goods* $\{c_i\}_i$ *and labor* l *to maximizes her utility as in (1.15);*

3. *Prices clear commodity markets in (1.20);*

4. *Aggregate price index, normalized to 1, clears the labor market (1.21).*

1.3.2 Analysis of Equilibrium

Before analyzing the model, I need to show the existence of ξ_i^l for $\forall\, i$ such that the Assumption 1 is satisfied. Proposition 3 describe a sufficient condition for the existence.

Proposition 3. *Under some appropriate assumption of parameters, for each sector* i, *there exists* $\underline{\xi}_i^l$ *and* $\bar{\xi}_i^l$ *such that for* $\xi_i^l \in [\underline{\xi}_i^l, \bar{\xi}_i^l]$, *Assumption 1 is satisfied.*
Proof: see Appendix A.6.

To prove the Proposition 3, I solve the model under Assumption 1, find the lower and upper bound of ξ_i^l for each i as $\underline{\xi}_i^l$ and $\bar{\xi}_i^l$ respectively, and verify the equilibrium. Therefore, $\xi_i^l \in [\underline{\xi}_i^l, \bar{\xi}_i^l]$ is just a sufficient but not necessary condition.

Then, I examine the pairwise correlations implied by the model. First, define

$$\Omega = \begin{bmatrix} \omega_{11} & \dots & \omega_{1N} \\ \vdots & \ddots & \vdots \\ \omega_{N1} & \dots & \omega_{NN} \end{bmatrix}, \ \Theta_m = \begin{bmatrix} \theta_{11}^m & \dots & \theta_{1N}^m \\ \vdots & \ddots & \vdots \\ \theta_{N1}^m & \dots & \theta_{NN}^m \end{bmatrix}, \ \mathbf{M}_\omega = \begin{bmatrix} \omega_{11} & & & \dots & \omega_{1N} & & \\ & \ddots & & \dots & & \ddots & \\ & & \omega_{N1} & \dots & & & \omega_{NN} \end{bmatrix},$$

$$\mathbf{D}_\alpha = \begin{bmatrix} \alpha_1 & & \\ & \ddots & \\ & & \alpha_N \end{bmatrix}, \ and \ \ \mathbf{D}_\pi = \begin{bmatrix} 1-\alpha_1-\sum_{j=1}^N \omega_{j1} & & \\ & \ddots & \\ & & 1-\alpha_N-\sum_{j=1}^N \omega_{jN} \end{bmatrix}$$

Also, define $\tilde{\nu} = (\mathbf{I} - \Omega' \diamond \Theta_m')^{-1}\nu$, where $\diamond$ is the Hadamard (entrywise) product and $\nu = [\nu_1, \dots, \nu_N]'$. Note that each element of $\tilde{\nu}$ corresponds the total value of sectoral outputs with the aggregate consumption, i.e.

$$p_i y_i = \tilde{\nu}_i c, \quad for \ \forall \ i \tag{1.22}$$

Let $\Delta \log y_t = [\Delta \log y_{1t}, \ldots, \Delta \log y_{Nt}]'$, $\Delta \log \theta_t^m = \left[\Delta \log \theta_{11,t}^m, \ldots, \Delta \log \theta_{1N,t}^m, \ldots, \log \theta_{N1,t}^m, \ldots, \log \theta_{NN,t}^m\right]'$, $\Delta \log z_t = [\Delta \log z_{1t}, \ldots, \Delta \log z_{Nt}]'$, and $\Delta \log \theta_t^l = \left[\Delta \log \theta_{1t}^l, \ldots, \Delta \log \theta_{Nt}^l\right]'$. Moreover, Lemma 2 implies that the value of vectors $\log \theta_t^m$ and $\log \theta_t^l$ only rely on these binding financial constraints, which further depend on the exogeneously bank lending shocks, e_i. Proposition 4 describes a solution for the vector of sectoral output growth.

Proposition 4. *Given the distortions on inputs, $\log \theta_t^m$ and $\log \theta_t^l$, the vector of sectoral output growth rates is*

$$\Delta \log y_t = (\boldsymbol{I} - \Omega')^{-1} \Big(\underbrace{\Delta \log z_t}_{\% \, \Delta \ in \ productivities} + \underbrace{\mathbf{M}_\omega \Delta \log \theta_t^m + \mathbf{D}_\alpha \Delta \log \theta_t^l + \left(\boldsymbol{I} - \Omega' - \mathbf{D}_\pi\right) \Delta \log \tilde{\nu}_t}_{Distortions \ caused \ by \ the \ Financial \ Friction} \Big) \tag{1.23}$$

Proof: see Appendix A.6.

Proposition 4 illustrates two sources that can affect the growth rates of sectoral outputs. The first one is sectoral productivity shocks. Second, distortions induced by the binding financial constraints also affect the sectoral outputs. If one sector receives a negative bank lending shock, which further causes the financial constraint binding, then the production will be distorted by this binding constraint.

Moreover, Proposition 4 highlights two transmission channels. The first one is the input-output linkage, which has been emphasized by the recent literature, such as Foerster et al. (2011), Gabaix (2011), Acemoglu et al. (2012), and Bigio and La'O (2017). With the Leontief inverse matrix, a negative productivity or bank lending shock to one sector can influence outputs of others through both direct and indirect linkages in intermediate inputs. Here, the 'direct' linkage describe the case where two sectors have trading relationship in intermediate inputs, whereas two sectors are 'indirectly' linked if they have trading relationship with a third sector, as either supplier or client or both. Also, two sectors can be both directly and indirectly connected. Note that, due to the Cobb-Douglas form of preference and technology, the shock can only be transmitted to the downstream sector through this channel. This is because the prices of goods in the upstream respond to the shock and perfectly offset the effects of the shock on its production. Relaxing the unitary elasticity of substitution, like

Atalay (2017) and Pinto and Young (2018), can generate the upstream transmission. I stick to the unitary assumption to keep the solution analytically tractable.

Furthermore, in addition to input–output linkage, the trade credit chain can propagate the negative bank lending shocks to other sectors. For example, firm A, B, and C from three different sectors and firm A provides intermediate inputs to B, which further supplies to C. Suppose that firm B receives a negative financial shock and become it financially constrained. Proposition 1 suggests that firm B will contract its provision of trade credit to firm C and instead ask for more CBD. Whether this adjustment in trade credit affect firm C's output depends on the firm C's financial condition. If firm C has sufficient amount of bank loans, it can use them to replace trade credit and fulfill the increased requirement for CBD. In this case, firm C's output will not be affected. However, if firm C is also financially constrained or on the edge of being financially constrained, such adjustment makes it more financially tightened or become so. In this case, the firm C's outputs will be also distorted by such a binding constraint. Moreover, this channel can transmit the financial shock to upstream as well. Proposition 1 also suggests that firm A will extend more trade credit. Lower requirement for CBD alleviates the firm B's financial constraints and further helps it to partially restore output. As in Kiyotaki and Moore (1997), if firm A has a deep pocket, firm A's output will not be affected. However, if firm A is also financial constrained, then such adjustment will make firm A more constrained, which further distorts firm A's output.

Here, the trade credit chain is the key to explain the asymmetric pattern of sectoral comovement observed in data. Over the normal economic recession, the financial conditions for many firms are relatively sound. Trade partners can adjust the issuance of trade credit to help out troubled firms. In this case, the trade credit chain is a cushion for bank lending shocks. It is less likely to observe a large scale of sectoral comovement. However, during the financial crisis, many firms experience trouble of borrowing from banks. In this case, the trade credit chain plays as a conduit by spreading the borrowing trouble to others, given the fact that it is the most important short-term finance source. Many firms' outputs are affected and it is very slikely to have an economy-wide contraction, i.e. high sectoral comovement.

1.3.3 Calibration

I calibrate the model with 15 two-digit industries in the U.S. economy.[24] These cover all private industries except FIRE. Table 5 describes parameters to be calibrated.[25] In particular, I use the IO table to calculate the share of intermediate inputs delivered from sector i to j over the gross value of sector j output as ω_{ij}. The intensity of trade credit in the neutral state $\left\{\bar{d}_i\right\}_i$ is matched to the median value of trade credit across public firms in each sector in 2007. The verification cost $\left\{\varphi_i\right\}_i$ is set to match the variance of trade credit provision from 2000 through 2007. In equilibrium, all firms with the low firm-specific productivities choose to default on their trade credit. Thus, κ is set to 0.06, which is the default rate of trade credit in Sweden as documented in Jacobson and von Schedvin (2016).

Then, the bank lending shocks for each sector are independent, following the log normal distribution $\log \mathcal{N}\left(0, (\sigma_i^e)^2\right)$. σ_i^e is estimated as the standard deviation of the bank lending index, proposed by Chodorow-Reich (2014), between 2002 and 2007. Suppose $\bar{e}_i^0$ is the bank lending condition where the financial constraint of firms in sector i are just binding. Then I set $\bar{e}_i$ such that the financial constraints are binding with one-third chance, fixing all intensities of trade credit are equal to the ones in the neutral state.

Next, I estimate the autocorrelation coefficients $\left\{\rho_i\right\}_i$ and the covariance σ_{ij}^z. In doing so, I first take the sectoral output growth rates from 2010Q1 to 2016Q4 in data, because the data before the Great Recession is too short to estimate. I start with the neutral state, and back up all series of the sectoral productivities using the sectoral output growth, assuming that no financial constraints are binding. Then, I use MLE to estimate Equation (1.8) for $\left\{\rho_i\right\}_i$ and σ_{ij}^z.

1.3.4 Limitation of Canonical Multi–sector Business Cycle Model

Before my analysis on the model with the endogenous trade credit structure, I test whether the canonical multi–sector business cycle model without the endogeneous trade credit structure can generate the three stylized facts documented in Section 1.2. To do so, I set all e_i sufficiently high such that all financial constraints are not binding. In this case, trade credit will always be equal to the natural levels. Now, the solution is same as in the canonical mod-

[24] I use 15 industries instead of 44 as in Section 1.2 because this choice allows me to identify a sufficient number of ‘financial’ recessions with a reasonable number of simulations in Section 1.3.5.

[25] Refer to Appendix A.7 for details.

el. Proposition 5 describes the correlations of output growth between two sectors implied by th is model.

Proposition 5. *Suppose e_i is sufficiently large for all sectors i such that no financial constraints are binding. Given any sequence of realizations $\Delta \log \mathbf{z}$, the correlation of output growth rates between sector i and j is*

$$\mathbf{corr}\left(\Delta \log y_i, \Delta \log y_j\right) = \sqrt{\frac{\delta_j \widetilde{\mathbf{M}}_{ij} \delta_i'}{\delta_i \widetilde{\mathbf{M}}_{ij} \delta_j'}} \tag{1.24}$$

where δ_i is the ith row of the Leontief inverse matrix $(\mathbf{I} - \Omega')^{-1}$, $\widetilde{\mathbf{M}}_{ij} = \mathbf{M}_z \delta_i' \delta_j \mathbf{M}_z$, and $\mathbf{M}_z = \frac{1}{T-1} \sum_t \Delta \log z_t \Delta \log z_t'$.

Proof: see Appendix A.6

Proposition 5 suggests that the output growth rate in any sector is a linear combination of percentage changes in sectoral productivities. The vector δ_i is the influence vector in Acemoglu et al. (2012), in which each element measures how much the sectoral output growth responds to a percentage change in each sector's productivity through direct and indirect linkages. No matter how much sectoral productivities are realized, the influence vectors stay the same. Moreover, the pairwise correlation only depends on how much their influence vectors differ. If one sector has the influence vector similar with the other's, outputs of both sectors evolve analogously and the pairwise correlation is high.

To examine how much the influence vectors differ across sectors, I apply the calibration in Section 1.3.3 and use two measurements, namely the Euclidean norm and the angular separation, to examine the difference.[26] The former measures the absolute distance between two vectors, while the latter calculates the cosine angle between them in the vector space, regardless of the length of vectors. The larger the Euclidean norm or the smaller the angular separation, the more two vectors differ. Table 6 shows the statistics for two distance

[26] The Euclidean distance and angular separation of weighted vectors between sector i and j are respectively

$$D^{EU} = \sqrt{\sum_{l=1}^{N} (\delta_{il} - \delta_{jl})^2}, \quad and \quad D^{AS} = \frac{\left| \sum_{l=1}^{N} \delta_{il} \delta_{jl} \right|}{\sqrt{\sum_{l=1}^{N} \delta_{il}^2} \sqrt{\sum_{l=1}^{N} \delta_{jl}^2}}$$

measurements. The means of Euclidean norm and angular separation are 1.58 and 0.14, respectively. These means with all other statistics show that the influence vectors are statistically different from each other and some of them are nearly orthogonal. The existence of significantly different influence vectors implies that the pairwise correlations are slightly positive on average, and this implication is consistent with my observations in data, where the pairwise correlations are about 0.15 on average before and after the Great Recession.

Then, I test Equation 1.24 by conduct the following regression:

$$\mathbf{Corr}_{ij} = \beta_0 + \beta_1 D_{ij}^{AS} + \gamma_i \mathbf{D}_i + \gamma_j \mathbf{D}_j + \epsilon_{ij} \tag{1.25}$$

where $\mathbf{Corr}_{ij}$ is the pairwise correlation of sectoral output growth rates between sector i and j, D_{ij}^{AS} is the angular separation of two influence vectors, and $\mathbf{D}_i$ is a dummy variable for sector i, controlling for sectoral fixed effects. Here, two values for pairwise correlation are used: namely the one before the Great Recession and the change during the Great Recession. As shown in Table 7, the coefficient of the angular separation measurement is positive and statistically significant for the pairwise correlation before the Great Recession. This result demonstrates the empirical relevance of the model without the endogenous trade credit structure, but the relevance only restrict to the data before the Great Recession. The coefficient for the change in the pairwise correlation is still positive but not statistically significant, indicating that only input-output linkage is not sufficient to deliver the significantly increase in sectoral comovement. To test the validity of the measurement, I also calculate the angular separations of row or column vectors of IO matrix, where $sup_i = [\omega_{i1}, \ldots, \omega_{iN}]$ and $cln_i = [\omega_{1i}, \ldots, \omega_{Ni}]$. These two distances measure how similar two sectors are as suppliers or clients. Unlike the one in the main regression, these two only count for direct linkage. The coefficients are positive but not statistically significant. It implies that the indirect linkage plays an important role in explaining the synergy among sectors before the Great Recession.

1.3.5 Simulation on the Model with Endogenous Trade Credit

In this section, I apply the calibration in Section 1.3.3 and conduct 10 million simulations of the model with the endogenous trade credit structure. Then I compare the kernel densities of pairwise correlations under different scenarios, and find that three stylized facts can be qualitatively replicated when the medium size of sectors receive negative bank lending shocks.

I define the real GDP in my model as the consumption bundle c in Equation (1.17). The volatility of the GDP growth across all simulated periods is 2.95%, which is comparable to the volatility of the US GDP growth rate in the last 20 years.[27] Following the classification of recession used by the National Bureau of Economic Research, I define some periods in a recession if the real GDP drops more than 1.5% for more than two consecutive periods. I also exclude two recessions if the latter starts within eight periods after the former ends. In this case, 67541 recessions are identified, covering 2.2% of total simulated periods. For each recession, I choose two periods before the recession as the starting point, calculate the pairwise correlations over eight periods since the starting point, and then take the kernel density. To compare, I also choose eight periods before and after the recession and repeat the same exercise. Figure 8 displays the average kernel density before, during, and after all recessions, compared to the one before the Great Recession with data. A few observations are noted. First, the kernel density generated by the model has slightly larger mean but smaller standard deviation than the corresponding statistics in data. It may be because the data used to estimate is from 2010 to 2016. Second, three kernel densities generated by data almost overlap one another, and no rise in sectoral comovement is observed during the recession.

Next, I restrict my analysis to two different types of scenarios. First, I define a recession as a 'severe' recessions if the average and the minimal GDP respectively drop more than 3.25% and 10.44%. Given the fact that the US GDP declined 2.8% in 2008 with the largest drop of 8.7% in 2008Q4, this criteria is aggressive because both counts in my definition are 20% more than ones during the Great Recession. In total, 2370 recessions are left, covering 0.08% of the simulated periods. The average drop in GDP during the 'severe' recession is 3.8%, compared to the average decline of 1.9% across all recessions. Second, I define a recession as a 'financial' recession if the financial constraints in more than three quarters of sectors are binding for at least two periods during the recession. Here, 365 episodes are categorized as financial recessions, covering 0.01% of the simulated periods. GDP during the 'financial' recession drops by 2.8% on average. Figure 9 displays the average kernel densities for different types of scenarios, namely 'non–financial', 'severe', and 'financial' recessions, compared to the one during the Great Recession with data. As shown in Figure 9, only the density during the 'financial' recession significantly shifts toward the right, as shown in the one with data. Moreover, the average of pairwise correlations during the financial recession in the model is 0.56, given that the average in data is 0.81. However, the density during

[27] All growth rates are measured at the compound annual rate.

the 'severe' moderately shifts to the right. This is consistent with evidence I find during the 1980 recession, which is also considered a 'severe' recession as the real GDP dropped by 1.9% in 1980, with the largest drop of 6.5% in 1982Q1.

Here, a few caveats should be noted. First, the pairwise correlations with 15 sectors is higher on average than ones with 44 sectors in Section 1.2. This is because the former one averages out the different dynamics of some sub–sectors under the same classification. Second, the binding financial constraint can be caused either by a negatively financial shock or by the adjustment in trade credit. In the 'financial' recession, on average, 60% of sectors with binding constraint receive negatively financial shocks. The rest become financial constrained because of the endogenous trade credit structure. Third, only 36 episodes are classified as both 'severe' recessions and 'financial' recessions.

Then, I perform the decomposition based on the extensive margin of sectoral interconnectedness, as in Section 1.2.3. Note that the IO matrix with 15 two-digit sectors is denser than the one used in the empirical analysis. I then set the element of the IO matrix equal to 0 if the intermediate share of total inputs is less than 0.5% instead of 0.1% using in Section 1.2.3. In this case, I have 85 pairs in the two-way trading group and 20 pairs in the one-way trading group. Figure 10 displays the average kernel density for two groups. As in stylized fact II, the average correlation in the two-way trading group is higher on average than the average in the one-way trading group.

Last, I perform the decomposition based on whether two sectors experience the decline in trade credit during the 'financial' recessions. Unlike the measurement in Section 1.2.4, I can observe bilateral trade credit between two sectors. Then, to examine the role of trade credit in sectoral comovement, I define a pair as experiencing a large decline in trade credit if the percentage change of the trade credit provided by either sector declines more than the median value across all pairs of sectors. Note that the mean of the median value for all financial recessions is 8.1%, which is slightly higher than the 6.3% in the data. Figure 11 displays the average kernel density for two groups. As in stylized fact III, the average correlation in the trade–credit decline group is higher on average than the counterpart group.

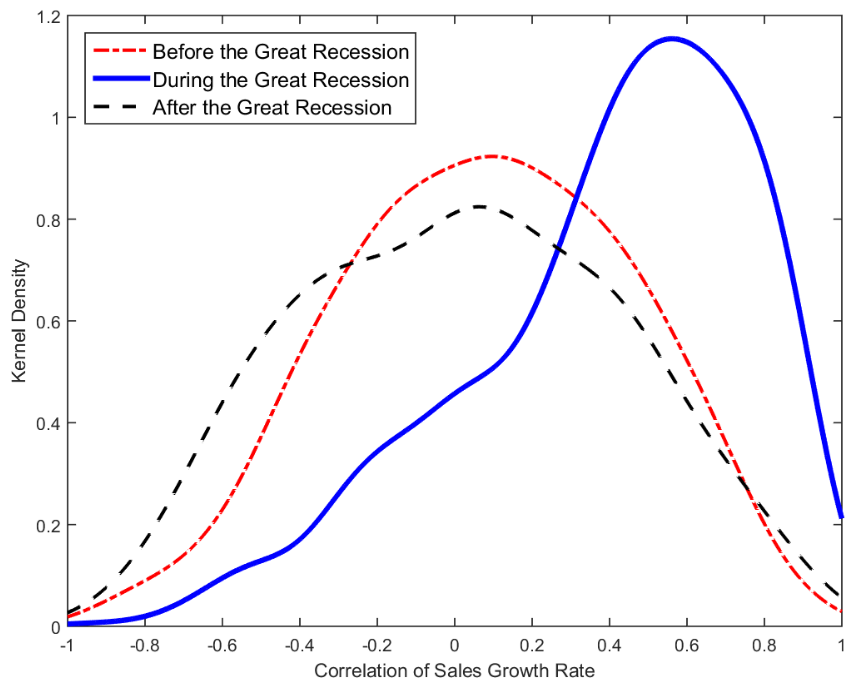
1.3.6 Counterfactual Analysis

I test what happens to the pairwise correlations and aggregate economic outcome (GDP) if the intensity of trade credit during the financial crisis cannot be adjusted. I first modify my model such that the trade credit during the financial recession is fixed to the level at one period before the recession starts. In this case, the model becomes isomorphic to the one in Bigio and La'O (2017). Using the same set of productivity and bank lending shocks, I recalculate the pairwise correlations and the kernel density. Figure 12 shows the comparison of the kernel densities with and without an endogenous trade credit structure. Without adjusting the trade credit, the shift in the density is modest in these recessions. Moreover, with a fixed trade credit, the average GDP drops by 2.3% on average across recessions. This outcome implies that the decline in trade credit during the financial recession amplifies shocks by about 18%.

1.4 Conclusion

In this paper, I document three new stylized facts about sectoral comovement in the United States during the Great Recession and set up a multisector general equilibrium model to explain them. Due to lack of information about bilateral agreement, trade credit, the most important short–term finance source, is under-studied by literature and often overlooked by policy maker. Here, I call for comprehensive dataset on trade–credit contracts. On the other hand, no specific regulation or capital buffer is required for trade credit, even though firms may carry substantial financial assets and liabilities on their balance sheets in the form of account payables and receivables. It is also important for policy maker to understand what kind of regulation could be imposed in order to deliver efficiency gains in this case?

Figure 1: Kernel Density for Pairwise Correlations during the Great Recession



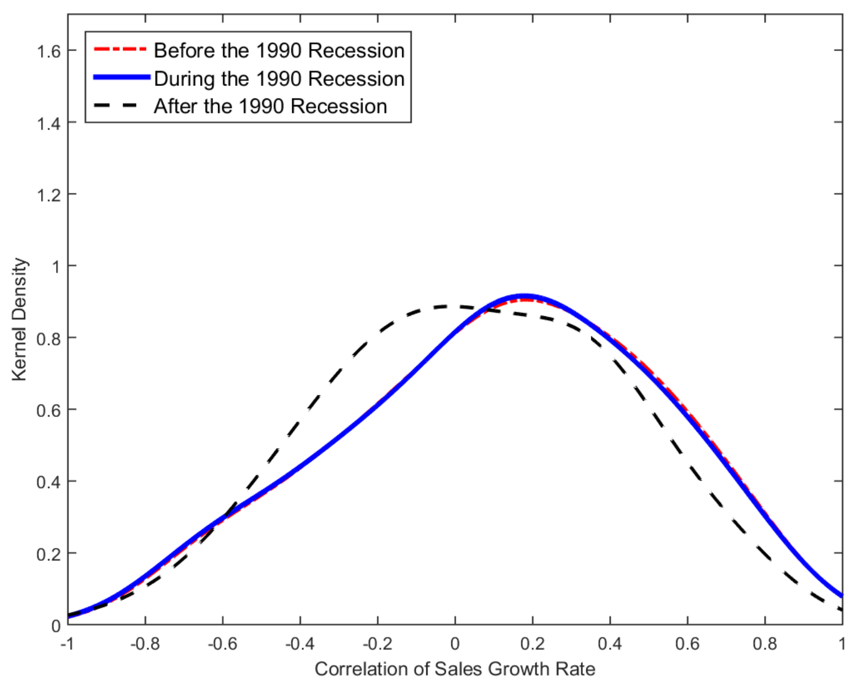
Note: The sectoral sales from the QFR are combined with the industrial gross output value by BEA. 2005Q3–2007Q2, 2007Q3–2009Q2, and 2009Q3–2011Q2, are chosen to represent before, during, and after the Great Recession, respectively. Equation (1.1) is used to calculate the pairwise correlation. The kernel density is applied to show the smoothed distribution of correlations for 946 pairs in each period. The dashed red, solid blue, and dotted black lines represent the densities before, during, and after the Great Recession, respectively.

Table 1: Pairwise Correlations of Output Growth Rates: Stylized Fact I

	Mean	Median	Std	Skewness	KS Statistics
the Great Recession					
Before the recession	0.08	0.09	0.38	-0.11	0.19 (0.00)
During the recession	0.38	0.46	0.38	-0.71	
After the recession	0.02	0.02	0.42	0.01	0.24 (0.00)
the 1990 recession					
Before the recession	0.11	0.14	0.41	-0.23	0.00 (1.00)
During the recession	0.11	0.14	0.41	-0.23	
After the recession	0.05	0.06	0.39	-0.06	0.04 (0.06)
the 2001 recession					
Before the recession	0.08	0.10	0.42	-0.12	0.03 (0.18)
During the recession	0.07	0.08	0.43	-0.10	
After the recession	0.12	0.14	0.39	-0.20	0.05 (0.01)
Comparison: across recessions					
the Great Recession vs the 1990 recession					0.19 (0.00)
the Great Recession vs the 2001 recession					0.23 (0.00)

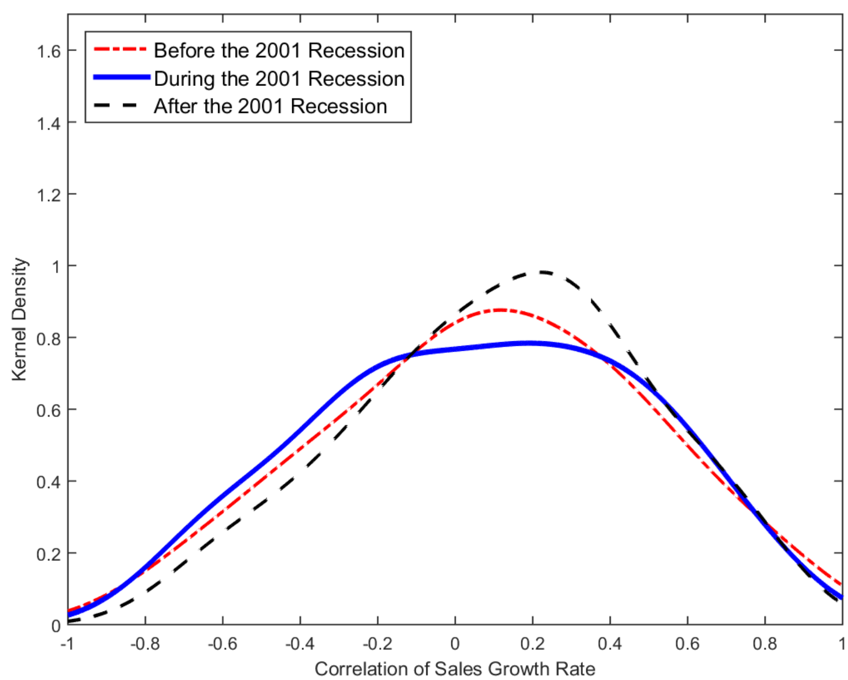
Notes: All kernel densities f are calculated on unit interval [1,1] with bandwidth 0.001. The *p-value* for the KS statistics is reported in the parentheses. The critical values of KS statistics at 0.1%, 1%, and 5% significance levels are respectively 0.0616, 0.0515, and 0.0430 in this case.

Figure 2: Kernel Density for Pairwise Correlations during the 1990 Recession



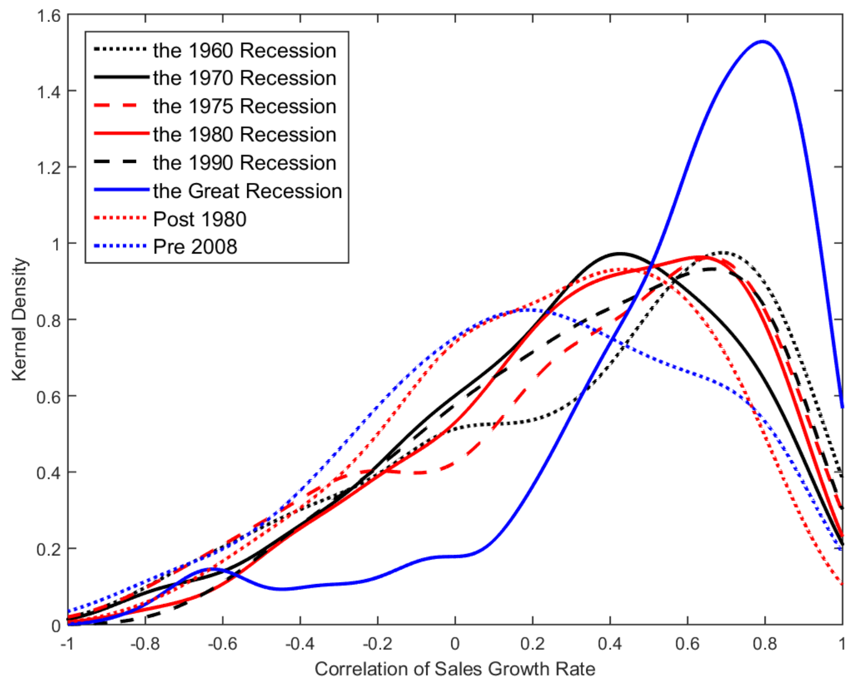
Note: Output data are from the QFR. The pairwise correlations are calculated as in Equation (1.1). 1989Q1–1990Q4, 1990Q1–1991Q4, and 1992Q1–1993Q4 are chosen to represent before, during. and after the 1990 recession, respectively. The dashed red, solid blue, and dotted black lines represent the densities before, during, and after the 1990 recession, respectively.

Figure 3: Kernel Density for Pairwise Correlations during the 2001 Recession



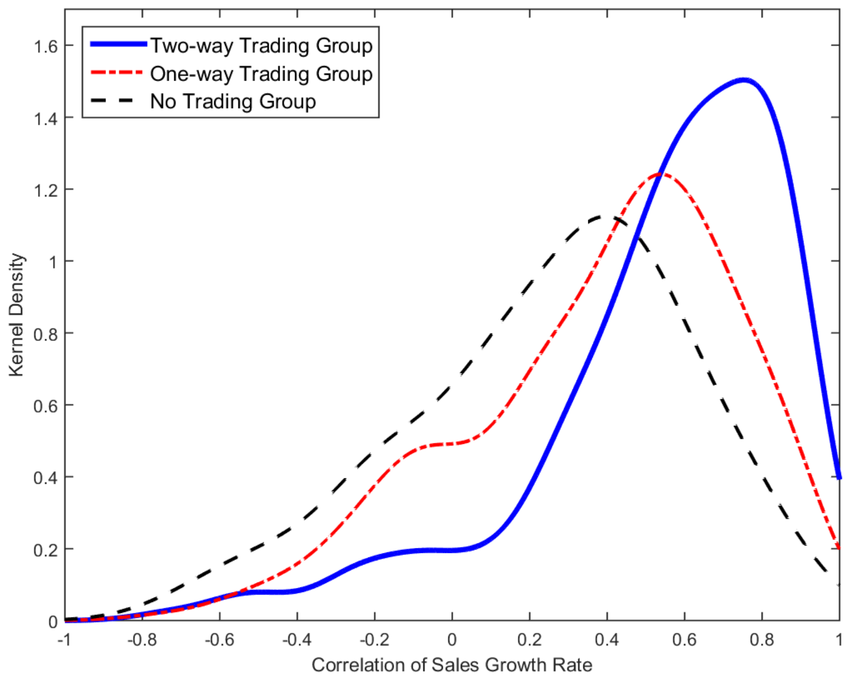
Note: Output data are from the QFR. The pairwise correlations are calculated as in Equation (1.1). 1998Q4–2000Q3, 2000Q4–2002Q3, and 2002Q4–2004Q3 are chosen to represent before, during, and after the 2001 recession. The dashed red, solid blue, and dotted black lines represent the densities before, during, and after the 2001 recession, respectively.

Figure 4: Kernel Density for Pairwise Correlations across Recessions



Note: Gross output values in annual frequency are provided by the BEA. The pairwise correlations are calculated as in Equation (1.1). The period starting points are respectively 1967, 1972, 1978, 1988, and 2005 for the 1970, 1975, 1980, 1990, and 2008 recessions, while 1983 for the post–1980 and 2000 for pre–2008 recession.

Figure 5: Kernel Density of Pairwise Correlations, by Extent of Interconnectedness



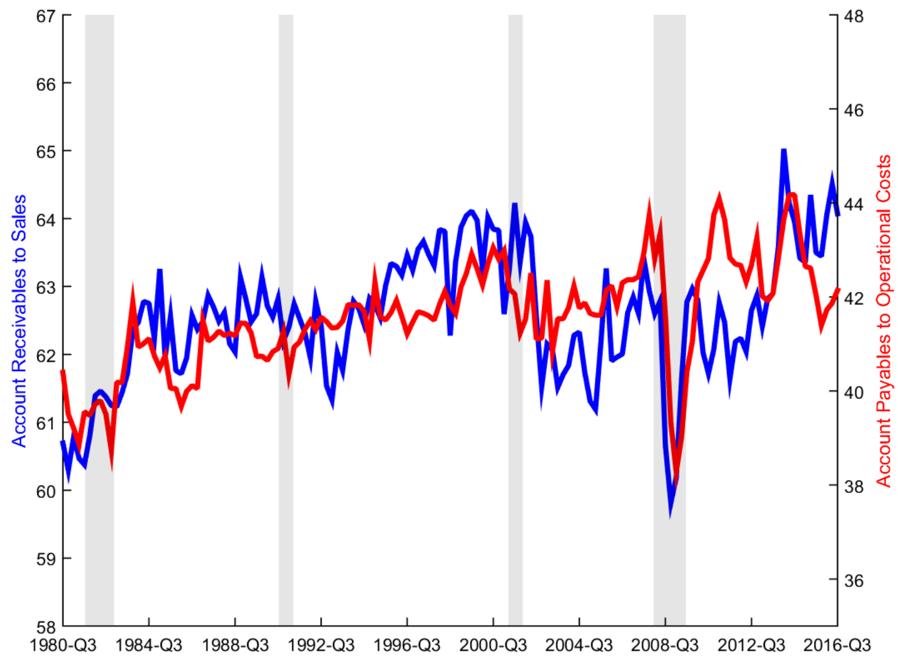
Note: Two-way trading group, in which two sectors are both intermediate inputs provider and purchaser to each other; one-way trading group, in which only one sector purchases intermediate inputs from the other but not vice versa; and no trading group, in which no intermediate input is traded between two sectors. There are respectively 381, 410, and 155 pairs in each group. Equation (1.1) is used to calculate the correlation of output growth rate. The solid blue, dashed red, and dotted black lines represent the densities for the two-way, one-way, and no-trade groups, respectively.

Table 2: Pairwise Correlations of Output Growth Rates: Stylized Fact II

	Mean	Median	Std	Skewness	KS Statistics
Two–way Trading Group					
Before the Great Recession	0.10	0.12	0.39	-0.20	0.27 (0.00)
During the Great Recession	0.50	0.60	0.34	-1.21	
After the Great Recession	0.01	0.01	0.44	0.05	0.36 (0.00)
One–way Trading Group					
Before the Great Recession	0.06	0.07	0.40	-0.04	0.17 (0.00)
During the Great Recession	0.33	0.40	0.37	-0.53	
After the Great Recession	0.01	0.03	0.41	-0.01	0.19 (0.00)
No Trading Group					
Before the Great Recession	0.06	0.07	0.36	-0.06	0.11 (0.00)
During the Great Recession	0.19	0.24	0.39	-0.35	
After the Great Recession	0.04	0.06	0.43	-0.06	0.11 (0.00)
KS Test across Groups during the Great Recession					
Two–way vs One–way					0.16 (0.00)
Two–way vs No Trading					0.23 (0.00)
One–way vs No Trading					0.09 (0.00)

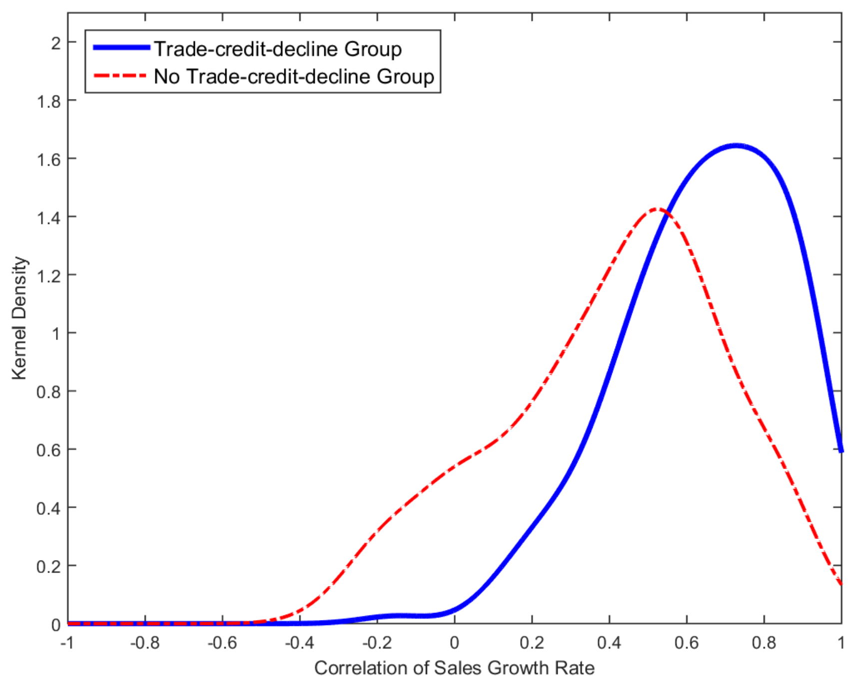
Notes: All kernel densities f are calculated on unit interval [1,1] with bandwidth 0.001. The *p-value* for the KS statistics is reported in the parentheses. The critical values of KS statistics at 0.1%, 1%, and 5% significance levels are respectively 0.0616, 0.0515, and 0.0430 in this case.

Figure 6: Evolution of Intensities of Trade Credit Provision and Reception



Note: I use the US public firms' data from Compustat to calculate the ratio of account receivables to output as the intensity of trade credit provision and the ratio of account payables to the sum of total operation costs and change in the inventory as the intensity of trade credit reception. Seasonality of both series is adjusted for each firm. The blue and red lines respectively represent the median value of trade credit provision and reception across firms in each period.

Figure 7: Kernel Density of Pairwise Correlations, by the Indicator of Decline in Trade Credit



Note: A pair is considered as experiencing trade credit decline during the Great Recession if both the intensity of the upstream sector's trade credit provision declined by more than 6.3% and the intensity of the downstream sector's trade credit reception declined by more than 6%. Otherwise, the pair is categorized into the control group. The blue solid and red dashed lines respectively represent the densities of group experiencing the decline in trade credit and the counterpart.

Table 3: Pairwise Correlations of Output Growth Rates: Stylized Fact III

	Mean	Median	Std	Skewness	KS Statistics
Group experiencing trade credit decline					
Before the Great Recession	0.08	0.10	0.39	-0.21	0.43 (0.00)
During the Great Recession	0.61	0.67	0.22	-0.36	
After the Great Recession	0.12	0.14	0.43	-0.12	0.43 (0.00)
Group not experiencing trade credit decline					
Before the Great Recession	0.09	0.10	0.37	-0.06	0.43 (0.00)
During the Great Recession	0.40	0.44	0.30	-0.39	
After the Great Recession	0.08	0.11	0.38	-0.22	0.43 (0.00)
KS Test across groups during the Great Recession					
Decline vs No Decline					0.19 (0.00)

Notes: All kernel densities f are calculated on unit interval $[-1, 1]$ with bandwidth 0.001. *p-value* for the KS statistics is reported in the parentheses. The critical values of KS statistics at 0.1%, 1%, and 5% significance level are respectively 0.0616, 0.0515 and 0.0430 in this case.

Table 4: Increase in Pairwise Correlations

	$\mathbf{D}^{tc} = 1$		$\mathbf{D}^{tc} = 0$		Diff	
	Obs	Mean of Δ**corr**	Obs	Mean of Δ**corr**	Mean	t-stat
$\mathbf{D}^{tf} = 1$ and $\mathbf{D}^{bl} = 1$	47	0.66	66	0.43	0.23	3.09
$\mathbf{D}^{tf} = 0$ and $\mathbf{D}^{bl} = 1$	24	0.56	87	0.32	0.24	2.23
$\mathbf{D}^{tf} = 1$ and $\mathbf{D}^{bl} = 0$	45	0.56	80	0.51	0.06	0.75
$\mathbf{D}^{tf} = 0$ and $\mathbf{D}^{bl} = 0$	26	0.53	100	0.29	0.24	2.54

Notes: All kernel densities f are calculated on unit interval $[-1, 1]$ with bandwidth 0.001. *p-value* for the KS statistics is reported in the parentheses. The critical values of KS statistics at 0.1%, 1%, and 5% significance level are respectively 0.0616, 0.0515 and 0.0430 in this case.

Table 5: Calibration

Parameters		Source/Target	Value
N	number of sectors	2-digit industries in the US	15
α_i	labor share	sectoral labor share	Appendix A.7
ω_{ij}	intermediates share	the U.S. IO table (2007)	Appendix A.7
φ_i	TC adjustment cost	var of TC (2000–2007)	Appendix A.7
$\bar{d}_i$	TC in the neutral state	median TC (2007)	Appendix A.7
ρ_i	autocorrelation for productivities	estimated by author	Appendix A.7
σ^z_{ij}	covariance of ϵ^z_i and ϵ^z_j	estimated by author	Appendix A.7
$\bar{e}_i$	mean of bank lending condition	calculated from the neutral state	Appendix A.7
σ^e_i	var of bank lending shocks	Chodorow-Reich (2014)	Appendix A.7
κ	prob of low proudctivities	Jacobson and von Schedvin (2016)	0.06
η	disutility from working	standard	1.9

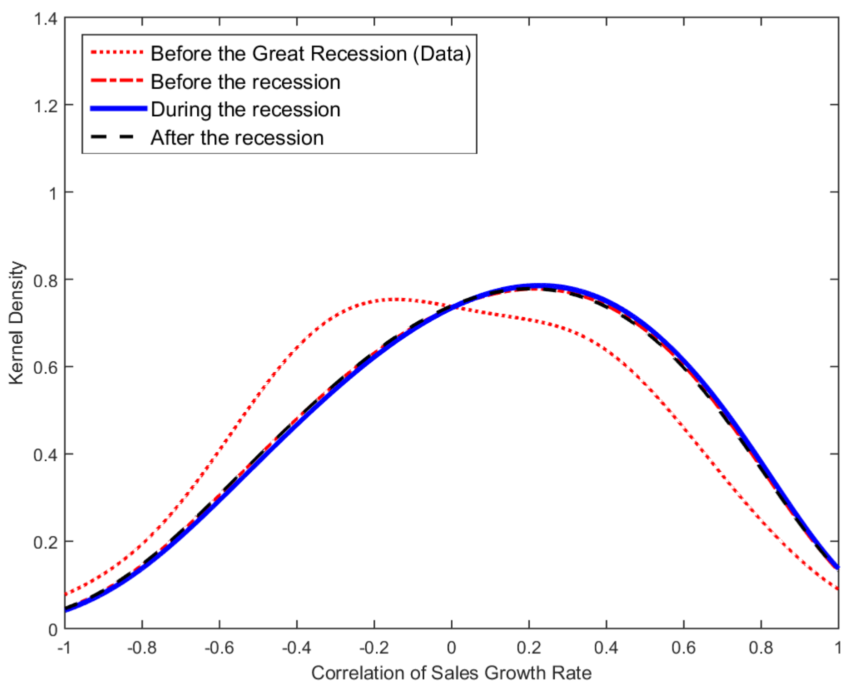
Table 6: Statistics: Distance Measure for Influence Vector δ_i

	Mean	Median	Std	Min	Max
Euclidean Norm	1.58	1.53	0.15	1.42	1.97
Angular Separation	0.14	0.11	0.10	0.01	0.46
	(82.0^o)	(83.7^o)		(88.3^o)	(62.7^o)

Table 7: Regression Results: Equation (1.25)

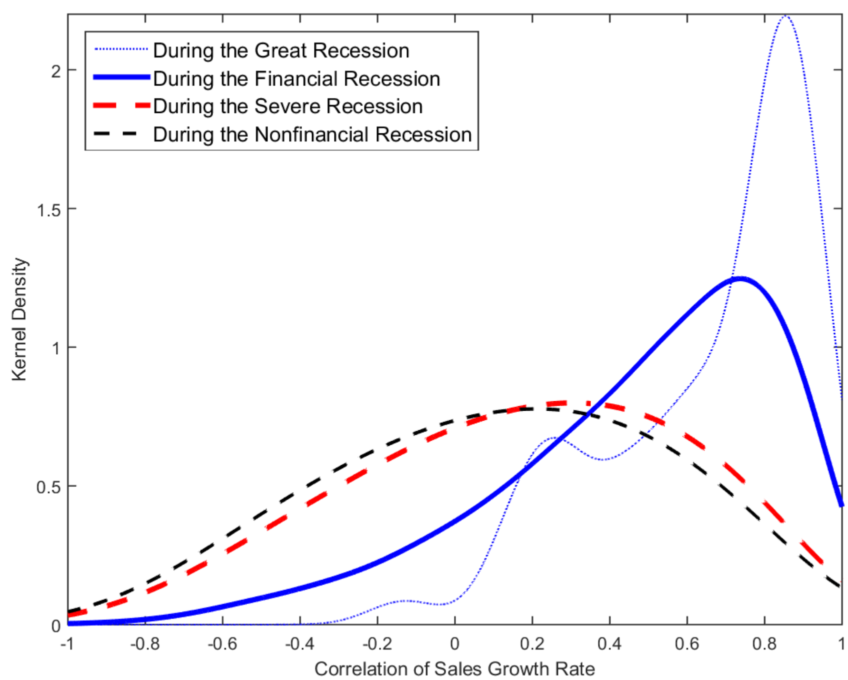
	$\mathbf{Corr}_{before}$				$\mathbf{Corr}_{crisis} - \mathbf{Corr}_{before}$	
$D^{AS}(\delta_i, \delta_j)$	1.11**	1.06*			.362	.658
	(.397)	(.541)			(.462)	(.691)
$D^{AS}(sup_i, sup_j)$			.193			
			(.172)			
$D^{AS}(cln_i, cln_j)$				.109		
				(.247)		
Sectoral FE	No	Yes	Yes	Yes	No	Yes
R^2	.0711	0.18	.0129	0.18	.00592	.751

Figure 8: Kernel Density: Simulation for Model with Endogenous Trade Credit



Note: A recession is identified if the real GDP drops more than 1.5% for more than two consecutive periods.

Figure 9: Kernel Density: Comparing Different Scenarios



Note: A recessions is categorized as a 'severe' recession if the average and the minimal GDP respectively drop more than 3.25% and 10.44% during the recession. A recession is categorized as a 'financial' recession if the financial constraints in more than three quarters of sectors are binding for at least two periods during the recession.

Figure 10: Kernel Density, by Extent of Interconnectedness

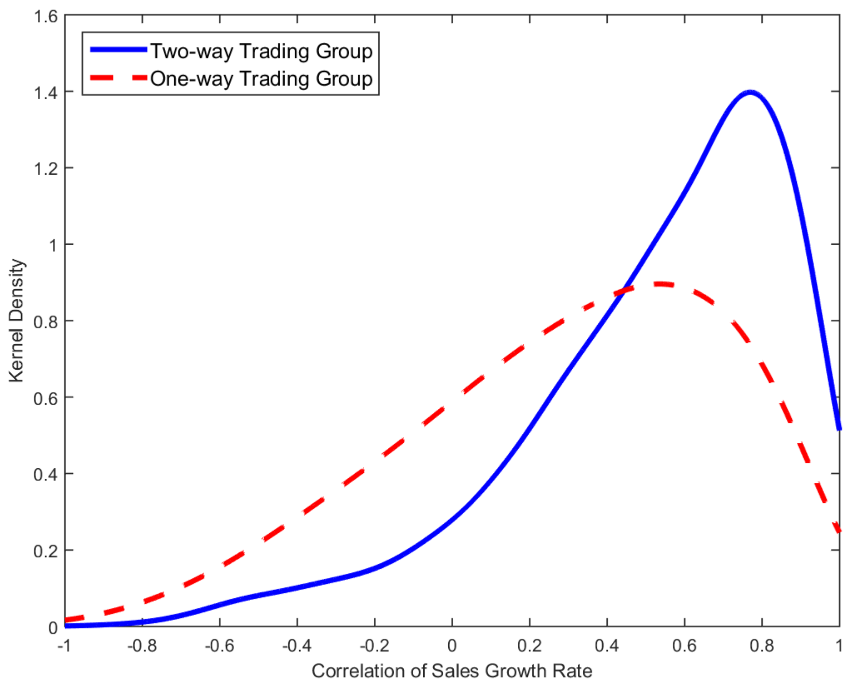


Figure 11: Kernel Density, by Extent of Interconnectedness

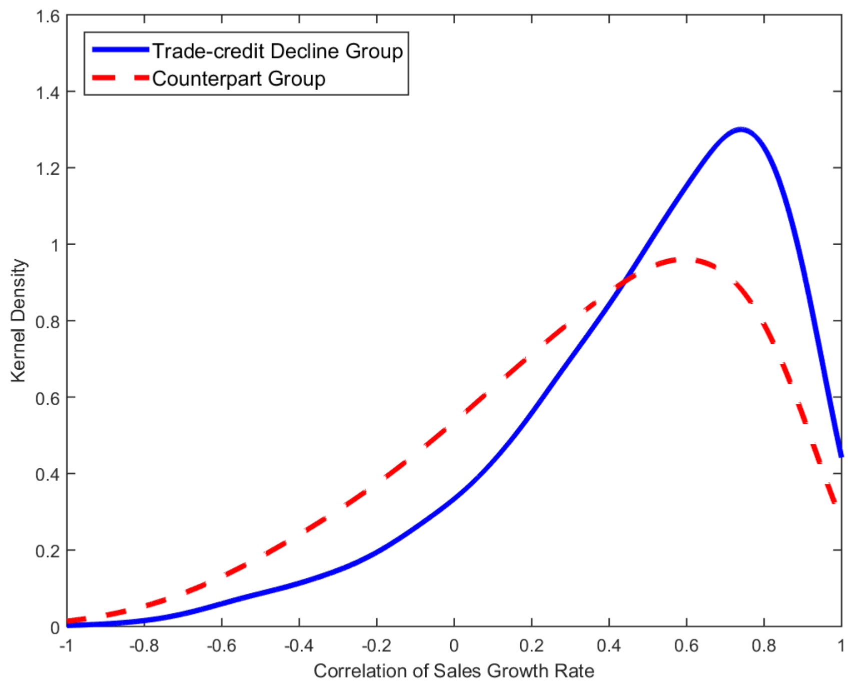
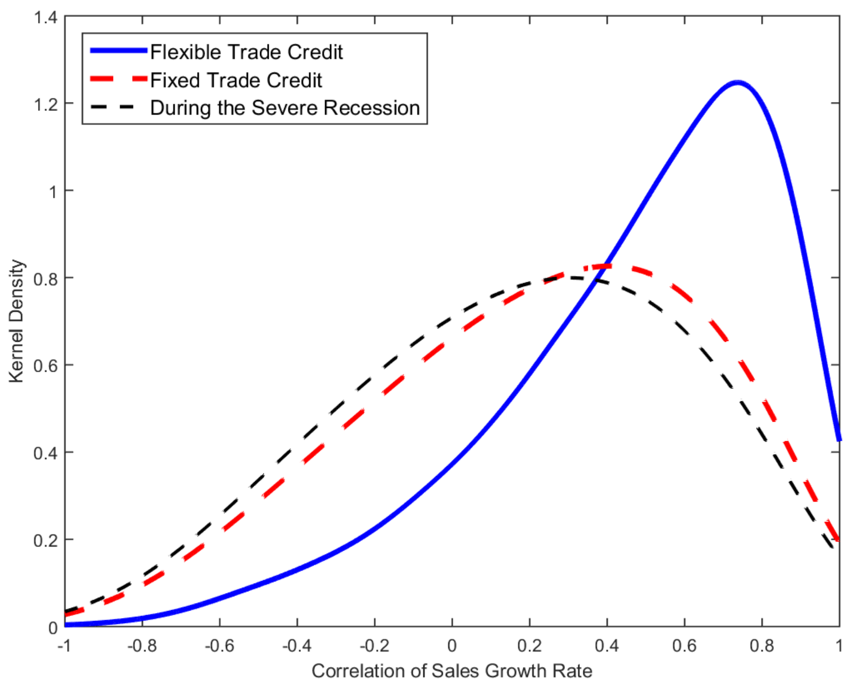


Figure 12: Kernel Density: Endogenous vs Fixed Trade Credit



Note: I fix the trade credit during the financial recessions to the level at one period before the recession starts. Using the same set of productivities and bank lending shocks, I recalculate the pairwise correlations and the kernel density.

Chapter 2

Jobs Before College Completion and Career Building of Young Workers Through Job Switching

Coauthored with Professor Toshihiko Mukoyama

2.1 Introduction

In the U.S. labor market, switching jobs is an important part of workers' career building. Hall (1982), using data from the Current Population Survey over the 1960s and 1970s, estimates that the average worker experiences more than 10 jobs over his working life. This job switching behavior is particularly important for young workers: in Hall (1982) study, nearly seven jobs are experienced by the age of 35. Furthermore, a well-known study by Topel and Ward (1992), using the Longitudinal Employer-Employee Data over 1957–1972, documents that in the first 10 years after entering the labor force, a young male worker experiences about seven jobs on average.

The studies of Hall (1982) and Topel and Ward (1992) have had a large influence on subsequent studies on earning dynamics, many of which confirm that job mobility plays an important role in earnings dynamics and other life-cycle decisions.[1] Evidence from various datasets support that workers on average experience wage gains when they move to new

[1] See, for example, Light (2001), Bagger et al. (2014), Altonji et al. (2013), and Lise (2013).

jobs.[2] In macroeconomic models of the worker life cycle, such as Esteban-Pretel and Fujimoto (2014), Jung and Kuhn (2015), and Menzio et al. (2016), job switching over the life cycle is one of the important ingredients in accounting for labor market dynamics. In particular, the fact that young workers experience many jobs is highlighted in these studies.

In this paper, we investigate what part of this job switching behavior is relevant for the career building of young workers. In contrast to previous studies, including Hall (1982) and Topel and Ward (1992), we focus on the distinction between jobs that are held while (or before) the workers attend college versus jobs after college. The motivation for our distinction is the observation that the reasons for working and job switching during college can be substantially different from the reasons for these after college, and therefore, these jobs may contribute differently to the subsequent career building of workers.[3] Our contribution is to document how much of the job-switching behavior is relevant for career building of young workers compared to the numbers put forth by Hall (1982) and Topel and Ward (1992).

We use the National Longitudinal Survey of Youth 1979 (NLSY79) dataset. This is a panel dataset of nationally representative samples of U.S. men and women. The NLSY79 provides the start and stop weeks of each employment spell for up to five jobs within the interview period since 1978. The advantage of this dataset over the ones used by Hall (1982) and Topel and Ward (1992) is that it contains the person's schooling information. We separate jobs held before and after the completion of the person's college degree and clarify how the total job holdings are divided into these two types of jobs.

We first show that there are many jobs that are held before college completion. We then show that the jobs that are held before and during college years have the following characteristics. First, the jobs before and after college completion consist of very different occupations. Second, the average wage paths of workers who experience many jobs in college and workers who do not look very similar. Although it is difficult to infer causality, these

[2]See, for example, Hyatt and McEntarfer (2012) and Tjaden and Wellschmied (2014).

[3]There is also a related literature of how early work experience affects future career success. This literature largely focuses on the jobs held during high school. See, for example, Baum and Ruhm (2016). Hotz et al. (2002) conduct a similar analysis to our wage regression in Appendix B.3 for both high school and college jobs and obtain a similar conclusion. We study a more homogeneous sample than their study (males who completed college at or before 23 years of age). Our focus is also different from theirs, as our main focus is the job switching behavior itself, rather than the wage dynamics. In the context of jobs during college, Light (2001) points out that the measurement of returns to schooling is affected once the job experienced during college is considered, while Häkkinen (2006) finds that with instrumental variable estimation there are no significant returns to student employment. Compared to these studies, we consider different types of jobs and also analyze occupational changes.

facts together can be interpreted that jobs before college completion contribute less to career building compared to the ones after college completion.

Following the past literature, we analyze the wage growth after college completion. The focus on wages implies that the channel of career building we consider is *human capital accumulation*. We also analyze occupational decisions of workers. This can also be important in the human capital context, provided that recent literature emphasizes the importance of occupation-specific human capital.[4] An entirely separate channel through which jobs held during college can affect the worker's future career is the *financing channel*. It may be the case that having jobs allows workers to finish college through relaxing their credit constraint, and thus contributes to a better future career.[5] Although a detailed analysis of credit constraint is beyond the scope of this paper, past studies using the NLSY79 dataset generally find that family income plays little role in college attendance.[6] However, newer studies find different effects in a different cohort (NLSY97), and this is a topic that requires further careful studies.[7]

Once we disregard jobs held before college completion, the average number of jobs experienced by a typical worker, counted similarly to Hall (1982) and Topel and Ward (1992), is fewer by one to three. Thus the numbers that are presented by Hall (1982) and Topel and Ward (1992) overestimate the number of jobs that are experienced by young workers for career building purposes. This can have important implications on how we should calibrate macroeconomic models of worker flows with the life cycle dimension.[8] For example, if we interpret the wage gain from job switching as the workers finding better matches, overestimating the number of jobs may lead to different quantitative implications of such activities.[9] Mukoyama (2014) argues that the slowing down of job-to-job transitions during recessions can have a significant effect on the aggregate productivity. In models that feature life-cycle

[4] See, for example, Kambourov and Manovskii (2009).

[5] With our samples, we run a simple Probit regression (not reported in the paper) to see how different factors are related to the probability of graduating, and we find that the annual average number of jobs held in college is negatively related to the probability of graduation, while the annual average wage rate and working hours for jobs before college completion have no statistically significant correlation with the probability of graduation. Thus we did not find any evidence that having many jobs helps students graduate, while it is difficult to infer causality from such a regression.

[6] See Lochner and Monge-Naranjo (2012) for a review.

[7] See, for example, Belley and Lochner (2007).

[8] Menzio et al. (2016) use the subgroup of high-school educated workers in their calibration, and thus avoid the issues raised in this paper.

[9] Consider, for example, the quantitative exercises of Barlevy (2002) and Mukoyama (2014).

elements, the adjustment we suggest can make a difference in the quantitative results of this type of theoretical experiments.

This paper is organized as follows. Section 2 describes the data. Section 3 presents our main results. Section 4 concludes.

2.2 Data

This section documents the basic statistics from our dataset. Further explanations about dataset construction are found in Appendix B.1.

2.2.1 NLSY79 dataset

The NLSY79 dataset contains 12,686 American youth, born between 1957 and 1964, as samples. They were first interviewed in 1979 at the age of 14 to 22. The NLSY79 provides up to five jobs' start and end dates, which we aggregate to an annual record.[10] To identify full-time jobs, we screen out all jobs in which employees work less than 30 hours per week or jobs which employees hold for less than 12 weeks if the associated hours-worked is missing.

We focus on the male samples with a high school education and above. We first screen out all military subsamples, all females, and all samples without high school diploma.[11] To avoid the left-censoring problem, we restrict our sample to respondents who entered the survey before they were 19 years old. Then we divide our sample into three groups according to their education levels: high school diploma, some college education but no degree, or college degree. These three groups respectively correspond to exactly 12 years, less than 16 but more than 12 years, and no less than 16 years of education.[12] Each category has 1,655, 710,

[10] The annual record is based on the survey year, since we do not have access to the respondents' birthdays.

[11] From 1991, economically disadvantaged white females and males in the supplemental subsample are not eligible for interview. We eliminate these samples as well.

[12] Because the NLSY surveys the highest years of education received as of May 1st of the survey year, some cases show that respondents reported the completed year of education in the middle of May at one year before the survey year. This will, in effect, underreport the actual year of education by one year. To adjust for this, we apply the following adjustments in considering the timing at which the sample completed the college education. First, for the respondents who reported to have attended the 16th year of education before August, not including August, of the year before the survey year, we consider them as having completed the college education in the previous year. Second, if information about the attending grade is not reported, if (i) respondents reported they were not enrolled in school as of the May 1st of the survey year and (ii) specified the reason for leaving school as 'Received Degree' between August of the year before the survey year and April of the survey year, then we consider them as completed college education before August. We

and 652 observations, respectively. We mainly focus on male college graduates who graduate at or before age 23. This subsample has 428 respondents. When we compute representative hourly wages for each year, they are deflated to 2009 dollars using the GDP deflater.

2.2.2 Basic patterns of job mobility

This section documents the basic patterns of job mobility. In order to facilitate comparison with the previous studies, we calculate some of the statistics that are shown in Topel and Ward (1992).

Table 8 corresponds to Table III B of Topel and Ward (1992). It describes how many jobs are held, on average, by a worker by each year since labor market entry. Here, *years since labor market entry* refers to years since the first time the worker had a full-time job after 18 years of age.[13] Here, only full-time jobs are counted.[14] For robustness, we repeat all our main exercises including part-time jobs in the online Appendix. All averages are computed using sample weights.

Table 8 shows that the basic job-switching pattern in our dataset is overall in line with the results in Topel and Ward (1992), reproduced in the last row. College graduates experience somewhat fewer jobs than other groups. Overall, an average worker experiences about seven to eight jobs in the first 10 years since labor market entry. Below, we use the sample of workers who completed college at or before age 23, which is presented in the fourth row of Table 8.[15]

Topel and Ward (1992) also document that the job transition serves as an important opportunity for wage growth. Table 9 shows that this holds true in our dataset, although the numbers are noisier due to the smaller sample size. Our result is also in line with Light (2005), who finds that the wage growth of all male college graduates is 66% on average

thank a referee for pointing out this issue.

[13] This is called "potential experience" in Topel and Ward (1992).

[14] Note that Topel and Ward's definition of "full-time job" is different from ours, due to different information contained in datasets. As mentioned above, we count jobs with more than 30 hours worked in one week as full-time jobs. Topel and Ward's dataset does not contain information on hours worked, and they define "full-time workers" as the workers who earned at least 70 percent of the quarterly minimum wage during that quarter. They also restrict the samples to white males, while our samples contain all males. Another slight difference from Topel and Ward (1992) is that they start the sample at the birth quarter of 18 years old, while we start at January of 18 years of age.

[15] For robustness, we repeat all our main exercises for the sample who completed college at or before 25 years of age in the online Appendix.

Table 8: Average cumulative full-time jobs by years since labor market entry

		Years since labor market entry									
	Obs	1	2	3	4	5	6	7	8	9	10
High School	1655	1.6	2.4	3.2	4.0	4.8	5.5	6.3	7.0	7.7	8.3
Some College	710	1.5	2.4	3.2	3.9	4.7	5.5	6.3	7.0	7.7	8.3
College	652	1.3	2.1	2.8	3.5	4.3	5.0	5.7	6.4	7.0	7.8
College ($\leq$ 23)	428	1.3	2.0	2.7	3.5	4.3	5.0	5.7	6.4	7.0	7.7
Full Sample	3017	1.5	2.3	3.1	3.8	4.6	5.4	6.1	6.8	7.5	8.1
Topel and Ward		1.6	2.5	3.2	3.9	4.6	5.1	5.7	6.1	6.5	7.0

Notes: Each cell describes how many jobs are held, on average, by a worker (with different educational attainment) by each year since labor market entry. All averages are computed using sample weights.

Table 9: Wage growth at job transition

	0−2	2−4	4−6	6−8	8−10
Wage Growth at Transition	15.6%	35.6%	24.4%	13.1%	10.0%
	0−2.5	2.5−5	5−7.5	7.5−10	
Topel and Ward	17.1%	11.9%	7.9%	5.7%	

Note: Each cell shows the average wage growth at each job transition, at different years since job market entry.

Table 10: Number of jobs held before college completion

Age	Obs	Average	Std	Min	25%	Median	75%	Max
≤21	125	2.9	1.7	0	1	3	4	7
22	181	3.6	2.0	0	2	3	5	10
23	122	4.4	2.1	0	3	4	6	11
≥24	224	7.6	3.9	1	5	7	10	23

Note: The table describes the number of jobs held before completing college, for the workers who graduated by the age of 21, at the age of 22, at the age of 23, at or after the age of 24.

during the first eight years of careers.

2.3 Results

In this section, we focus on the samples of male workers who graduated college at or before age 23. For these workers, jobs that are held before college graduation are likely to be temporary jobs that may not be closely related to their subsequent careers. In order to analyze career building of young workers, it is useful to distinguish between such jobs and ones held after college completion.

Table V of Topel and Ward (1992) already suggests the prevalence of such temporary jobs early in a worker's career. It shows that about 30 percent of jobs for a worker with no prior experience end within one quarter, followed by the worker moving to nonemployment. Here, we explicitly look at the job experience during college.

2.3.1 Significance of jobs held before college completion

Table 10 shows the number of jobs held before completing college, for the workers who graduated by the age of 21, at the age of 22, at the age of 23, at or after the age of 24. This indicates that these workers hold many jobs during the school year before completing college. We call these jobs *jobs before college completion* (JBCC). As shown in the table, the young males in our samples held 4.4 jobs on average before their graduation from college even if they complete college at the age of 23. In some extreme cases, 11 jobs are held before graduation from college for these samples.

Thus, JBCC occupy a substantial part of a young worker's job counts, and it is important to examine whether JBCC have any effects on young workers' career building. In the following, we examine how JBCC are different from the subsequent jobs and how experiences of JBCC affect the wage dynamics.

2.3.2 Career building and the jobs before college completion

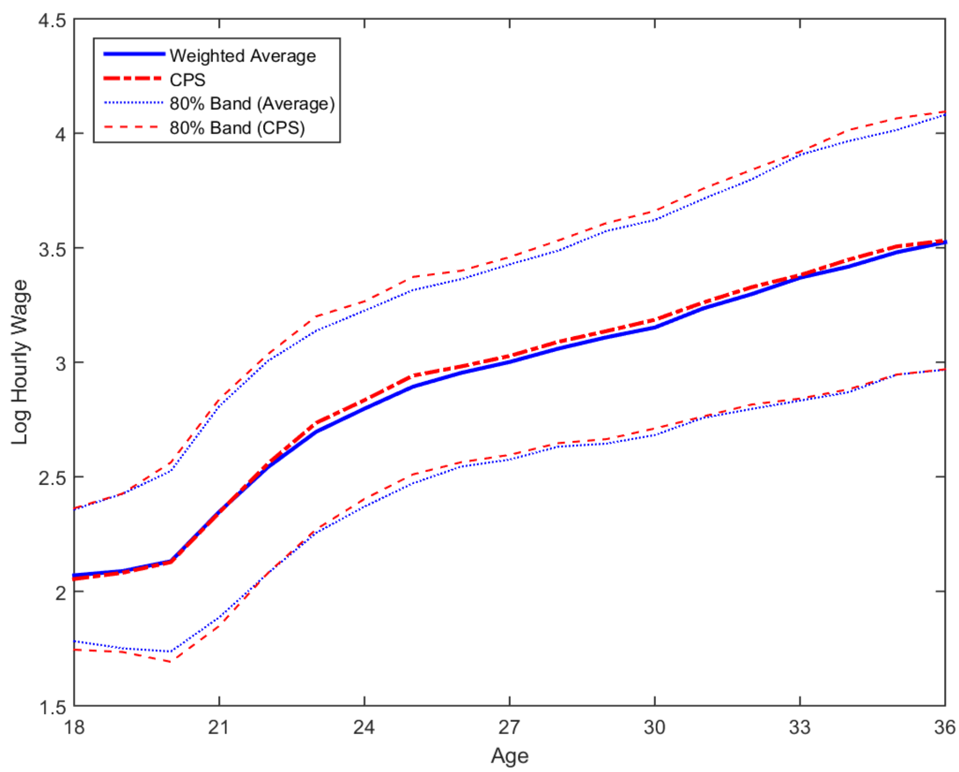
Here we examine whether jobs held before college completion play a different role from other jobs in young workers' career building. First, Figure 13 plots the average hourly wages for our sample. Two wage rates are considered. One is the weighted average of wage rates over *all jobs* held by respondents, and the other is the wage rates of the *CPS jobs*, which are defined as the current or the most recent jobs.[16] Throughout the rest of the paper, we use weighted average wage rates over all jobs. The two wage series exhibit a similar pattern: the wages are relatively low and flat at the beginning the college education, and the wage increases steeply afterward. This suggests that (the early part of) JBCC has different characteristics from the subsequent jobs.

Figure 13 also shows that the average wage starts to increase around the age 21. In fact, Figure 25 in Appendix B.2 shows that the wage starts increasing one year before graduation. To differentiate this part of JBCC, we conduct a separate analysis for the jobs held one year before graduation. It turns out that these jobs have a feature of the transition from typical college jobs to the future real jobs.

In Appendix B.3, to examine whether JBCC's wage is statistically different from the wage earned by jobs after college, we run Mincerian-style regressions. We find that the wages for JBCC are 15 to 26 percent lower, and the difference is statistically significant. While this difference would contain the returns to college education, similar differences are observed for samples who did not complete college. These regressions also suffer from issues with selection bias, and thus it is difficult to tease out a causal relationship. However, they are consistent with our observations in Figure 13 that JBCC's wages are significantly lower compared to the wages of the subsequent jobs.

[16]The name comes from the fact that the definition here is consistent with the definition of employment in the Current Population Survey (CPS). See Appendix B.1 for details.

Figure 13: Average wage paths (2009 dollar)



Notes: The middle lines are the average log hourly wages for all jobs (solid line) and the CPS jobs (dash-dot line). The 80% confidence bands are also shown.

Patterns of occupational choice

We next look at the differences in occupation for JBCC and subsequent jobs.[17] Table 11 lists top-10 three-digit occupations for all JBCC, JBCC one year before graduation, and subsequent jobs in the first five years of the workers' careers. The last column shows four large occupational categories, which follow the classifications by Acemoglu and Autor (2011): 1. nonroutine cognitive, 2. routine cognitive, 3. routine manual, and 4. nonroutine manual. With the exception of "Waiters," the top-10 occupations before and after college are entirely different. The top-10 occupations for JBCC are largely manual occupations, while all top-10 subsequent jobs are in nonroutine cognitive occupations. JBCC are also typically in low-wage occupations.

The jobs one year before college graduation have features that are similar to all JBCC. They, however, also have transitional features towards the jobs after college. For example, Acemoglu and Autor (2011) nonroutine cognitive (category 1) jobs start to appear.

Tables 12 and 13 show the distribution and average wages of different occupational groups. Table 12 looks at ten occupational categories defined in the Dictionary of Occupational Titles (DOT) and Table 13 uses the four categories from Acemoglu and Autor (2011). These tables deliver a similar message to Table 11: the occupational characteristics of JBCC and subsequent jobs are very different. The jobs one year before college graduation are, again, similar to typical JBCC but also have transitional features. For example, in Table 12, the categories "professional" and "managers," which are prevalent after college completion but less observed in JBCC, display in-between numbers one year before college completion. For "labors" and "farm labors," we observe the opposite pattern: they are popular as JBCC but less so after college, and in-between for one year before college graduation.

Since the results in Tables 11, 12, and 13 may reflect a natural career progression due to age, because the "after" jobs include all subsequent jobs, in Tables 14 and 15 we compute the occupational transition matrices between the last job before college graduation and the first job after college graduation. Each cell (i, j) represents the fraction of workers moving from a category i job to category j job. There, the effect of age is minimal, because these tables look at two consecutive jobs.

We observe that there is a large mobility across occupational categories. Table 15 shows

[17] In Appendix B.6, we repeat similar exercises for differences in industries. It turns out that industry differences do not exhibit as clear patterns as occupations. This echoes Kambourov and Manovskii (2009) finding that occupations are more important than industries for specific human capital accumulation.

Table 11: Top 10 occupations before and after college graduation

Group	Name	Proportion	Wage	Categories
Before				
755	Gardeners and Grounds Keepers	8.1%	6.6	4
780	Miscellaneous Laborers	4.1%	8.1	4
751	Construction Laborers	3.6%	11.1	4
932	Attendants	3.6%	6.7	4
310	Cashiers	2.9%	6.8	2
903	Janitors and Sextons	2.9%	7.4	4
762	Stock Handlers	2.6%	7.0	4
912	Cooks	2.6%	8.5	4
822	Farm Laborers	2.4%	7.2	4
915	Waiters	2.4%	12.0	4
One Year Before College Graduation				
755	Gardeners and Grounds Keepers	7.4%	6.8	4
902	Building Interior Cleaners	5.3%	5.2	4
903	Janitors and Sextons	4.2%	8.0	4
153	Electrician	3.2%	13.1	1
245	Managers and Administrators	3.2%	9.8	1
441	Blue-collar Worker Supervisors	3.2%	15.4	3
510	Painters, Construction and Maintenance	3.2%	11.6	3
780	Miscellaneous Laborers	3.2%	9.5	4
962	Guards	3.2%	7.2	4
14	Mechanical Engineers	2.1%	13.4	1
After				
245	Managers and Administrators	8.2%	15.8	1
3	Computer Programmers	3.4%	20.6	1
142	Elementary School Teachers	2.8%	14.1	1
1	Accountants	2.6%	18.8	1
231	Sales Managers	2.3%	13.8	1
23	Engineers	2.0%	24.6	1
76	Therapists	2.0%	12.9	1
230	Restaurant Managers	2.0%	13.2	1
915	Waiters	2.0%	16.5	4
162	Engineering and Science Technicians	1.7%	26.1	1

Notes: The table lists top-10 three-digit occupations for all JBCC, JBCC one year before graduation, and subsequent jobs in the first five years of the workers' careers. It also shows the proportion, average wages, and Acemoglu and Autor's (2011) occupation categories.

Table 12: Distribution of ten occupation categories: before and after

		Before		**1Y Before CG**		**After**	
Group	Categories	Proportion	Wage	Proportion	Wage	Proportion	Wage
1	Professional	12.7%	10.3	17.9%	11.2	41.2%	17.6
2	Managers	3.8%	9.7	5.3%	9.7	14.8%	15.1
3	Sales	1.0%	6.1	2.1%	11.3	4.3%	20.5
4	Clerical	14.6%	8.1	16.8%	7.6	12.2%	17.9
5	Craft	9.6%	10.7	12.6%	11.7	5.4%	15.8
6	Operative	7.2%	10.2	8.4%	11.2	3.1%	12.7
7	Transportation	4.3%	8.0	3.2%	9.5	4.3%	10.4
8	Labors	21.5%	7.7	11.6%	7.1	5.4%	9.8
9	Farmers	NA	NA	NA	NA	0.6%	6.5
10	Farm Labors	25.4%	7.7	22.1%	8.3	8.8%	12.8

Notes: The table shows the distribution and average wages of different occupation groups; before college graduation, one year before college graduation, and after college graduation. This table looks at ten occupational categories defined in the DOT.

Table 13: Distribution of four occupation categories: before and after

		Before		**1Y Before CG**		**After**	
Group	Categories	Proportion	Wage	Proportion	Wage	Proportion	Wage
1	Nonroutine Cognitive	16.5%	10.2	23.2%	10.9	56.0%	16.9
2	Routine Cognitive	15.6%	8.0	18.9%	8.1	16.5%	18.6
3	Routine Manual	21.1%	10.0	24.2%	11.3	12.8%	13.2
4	Nonroutine Manual	46.9%	7.7	33.7%	7.8	14.8%	11.5

Notes: The table shows the distribution and average wages of different occupation groups; before college graduation, one year before college graduation, and after college graduation. This table looks at four occupational categories defined in Acemoglu and Autor (2011).

Table 14: Transition matrix across occupation categories (%)

From \To	1	2	3	4	5	6	7	8	9	10
1	55.0	10.0	10.0	5.0	5.0	5.0	0.0	5.0	0.0	5.0
2	33.3	33.3	0.0	0.0	0.0	0.0	0.0	22.2	11.1	0.0
3	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0
4	52.6	21.1	15.8	5.3	0.0	0.0	5.3	0.0	0.0	0.0
5	12.5	12.5	0.0	25.0	25.0	12.5	0.0	12.5	0.0	0.0
6	66.7	0.0	0.0	16.7	0.0	0.0	0.0	16.7	0.0	0.0
7	66.7	0.0	0.0	0.0	0.0	0.0	33.3	0.0	0.0	0.0
8	36.8	5.3	10.5	5.3	10.5	0.0	5.3	15.8	0.0	10.5
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	34.3	11.4	2.9	14.3	5.7	2.9	5.7	8.6	2.9	11.4

Notes: The table shows the occupational transition matrix between the last job before college graduation and the first job after college graduation. This table looks at ten occupational categories defined in the DOT.

Table 15: Transition matrix across occupation categories (%)

From \To	1	2	3	4
1	65.5	10.3	6.9	17.2
2	71.4	23.8	4.8	0.0
3	50.0	15.0	25.0	10.0
4	44.4	16.7	14.8	24.1

Notes: The table shows the occupational transition matrix between the last job before college graduation and the first job after college graduation. This table looks at four occupational categories defined in Acemoglu and Autor (2011).

that the outward mobility is especially pronounced in manual categories (categories 3 and 4), in which the majority of JBCC are classified. This indicates that the majority of JBCC tend to be of different types of jobs that are not closely related to subsequent career building.[18]

JBCC and subsequent career

To further see how JBCC experiences affect the worker's subsequent career, we calculate the wage paths for subsamples who experienced JBCC and for these who did not experience any JBCC. Figure 14 plots the weighted average wage paths for workers who held any job during school before completing college versus workers who did not. Appendix B.4 plot similar figures for different numbers of jobs, subsamples based on *summer jobs* (defined as jobs held during the May 1 to August 31 period), subsamples that experienced *temporary jobs* (jobs shorter than 12 weeks that are not summer jobs), and subsamples with jobs that are neither summer nor temporary jobs (we call them *regular long-term jobs*). All figures indicate that the average wage paths are remarkably similar. This suggests that job experiences before college completion are different in nature from the experiences in the subsequent jobs, and the JBCC do not have significant contributions to subsequent wage growth.[19]

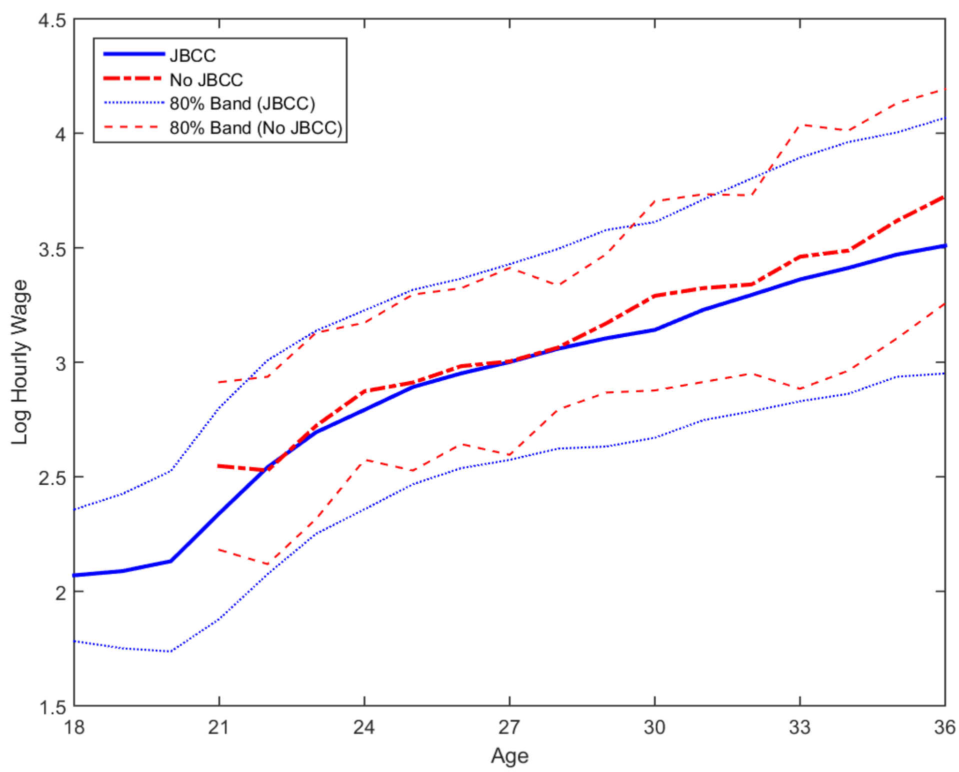
Table 16 looks at the duration of the first job after graduation. If the JBCC contributes to the career building process, the first job after graduation should last longer for the workers with JBCC experiences. The upper panel summarizes statistics from all jobs, and the lower panel restricts to the situation where the second job comes within four weeks after finishing the first job. In both panels, having JBCC does not change the duration of the first job, except for the cases of without regular long-term jobs and without any JBCC. These cases tend to have a shorter duration of the first job. However, they suffer from a rather extreme small-sample issue and it is difficult to draw strong conclusions from these numbers. Table 17 calculates the wage changes after the first job. There, the numbers are noisier, but we do not see systematic differences except for the cases with very small sample sizes.

Table 18 calculates the average cumulative full-time jobs after completing college across different groups of workers. The cumulative number of jobs are remarkably similar across groups who had different work experiences during college. This suggests that the jobs during

[18]Appendix B.7 conducts a more detailed analysis of the patterns of occupational choice before and after college graduation.

[19]Appendix B.3 conducts formal statistical analyses, including regressions that control for endogeneity by the Heckman correction. The results are consistent with these figures.

Figure 14: Average wage paths for samples with and without JBCC (2009 dollar)



Notes: The middle lines are the average log hourly wages for the samples with JBCC (solid line) and without JBCC (dash-dot line). The 80% confidence bands are also shown.

Table 16: Duration of the first job (weeks)

	Obs	Mean	Std	10%	Median	90%
All Sample						
With Summer Jobs	251	57	38	11	56	107
Without Summer Jobs	170	62	39	13	60	109
With Temporary Jobs	69	55	38	12	42	105
Without Temporary Jobs	352	60	39	11	59	108
With Regular Long-term Jobs	316	63	40	13	62	111
Without Regular Long-term Jobs	105	46	32	10	38	90
With JBCC	390	60	39	12	58	109
Without JBCC	31	51	32	10	59	93
1st and 2nd Job Gap $\leq$ 4 weeks						
With Summer Jobs	152	71	37	12	79	113
Without Summer Jobs	99	74	38	20	74	112
With Temporary Jobs	33	76	37	8	87	111
Without Temporary Jobs	218	71	38	17	77	113
With Regular Long-term Jobs	191	76	38	20	82	115
Without Regular Long-term Jobs	60	60	34	11	68	97
With JBCC	229	73	38	14	80	113
Without JBCC	22	63	30	16	66	98

Note: The table shows the duration of the first job after graduation.

Table 17: Wage changes after the first job

	Obs	Mean	Std	10%	Median	90%
All Sample						
With Summer Jobs	213	39.6%	98.6%	−22.0%	17.6%	110.7%
Without Summer Jobs	152	22.5%	60.2%	−36.2%	12.6%	68.0%
With Temporary Jobs	62	34.5%	85.2%	−43.8%	14.3%	111.8%
Without Temporary Jobs	303	32.1%	85.1%	−22.5%	13.7%	88.1%
With Regular Long-term Jobs	281	29.6%	80.9%	−25.6%	13.1%	84.7%
Without Regular Long-term Jobs	84	42.0%	97.6%	−23.8%	22.4%	115.5%
With JBCC	338	32.6%	87.8%	−28.9%	13.4%	94.6%
Without JBCC	27	31.3%	35.5%	0.8%	24.8%	64.4%
1st and 2nd Job Gap $\leq$ 4 weeks						
With Summer Jobs	137	25.2%	60.3%	−17.4%	16.8%	77.2%
Without Summer Jobs	94	20.2%	34.5%	−16.7%	13.6%	60.1%
With Temporary Jobs	29	17.3%	39.8%	−23.9%	13.3%	64.9%
Without Temporary Jobs	202	24.1%	52.9%	−16.8%	16.4%	66.8%
With Regular Long-term Jobs	179	18.0%	38.1%	−18.3%	12.8%	61.1%
Without Regular Long-term Jobs	52	41.1%	80.1%	−4.5%	25.1%	88.8%
With JBCC	211	22.5%	53.3%	−18.3%	13.5%	67.5%
Without JBCC	20	30.3%	21.9%	9.3%	26.1%	61.3%

Note: The table shows the wage changes after the first job.

Table 18: Average cumulative full-time jobs after completing college

	1	2	3	4	5	6	7	8	9	10
With Summer Jobs	0.7	1.5	2.3	2.8	3.6	4.2	4.9	5.5	6.2	6.7
Without Summer Jobs	0.6	1.2	2.0	2.7	3.4	4.1	4.8	5.3	5.9	6.5
With Temporary Jobs	0.7	1.3	2.2	2.8	3.5	4.3	5.1	5.8	6.4	6.9
Without Temporary Jobs	0.7	1.4	2.2	2.8	3.5	4.1	4.8	5.4	6.0	6.6
With Regular Long-term Jobs	0.7	1.4	2.2	2.8	3.5	4.2	4.9	5.5	6.1	6.6
Without Regular Long-term Jobs	0.7	1.4	2.2	2.8	3.5	4.1	4.8	5.4	6.0	6.5
With JBCC	0.7	1.4	2.2	2.8	3.5	4.1	4.9	5.4	6.1	6.6
Without JBCC	0.5	1.1	2.2	2.7	3.6	4.3	5.1	5.6	6.3	6.9

Note: The table shows the average cumulative full-time jobs after completing college across different groups of workers.

college have little influence on the subsequent job-switching process, consistent with the results in Tables 16 and 17. This also implies that there is no indication of strong selection among different groups—the characteristics of the workers who experienced JBCC do not seem to be very different from the characteristics of the workers who did not.

The conclusion from the above results is that JBCC, especially summer jobs and temporary jobs, are relatively disconnected from workers' subsequent career. In a context of job-ladder type models, which assume that workers build their careers by moving up the ladder, one can reasonably argue that these jobs should not be included as a part of the career-building process.

2.3.3 Adjusted total number of jobs

Considering that jobs held during college contribute little to the overall career-building over the life cycle, it is of interest to calculate the total number of *career-contributing jobs*.

Table 19 repeats Table 8 for the samples of male workers who graduated college before age 24.[20] Jobs in Type 1 exclude summer jobs. Jobs in Type 2 exclude temporary jobs. Jobs

[20] Here, we drop respondents who do not have at least 8 consecutive observations since labor market entry. Topel and Ward (1992) makes an effort to eliminate the individuals whose careers start with summer jobs (see their footnote 21) in their Section III. There, they only consider workers who had full-time work over more than four quarters at the entry. This eliminates over 90% of individuals (the number of individuals fell from 9,919 to 872) while the number of full-time jobs does not fall as much (it fell from 58,181 to 44,089). It has to be noted that their Table III include all white male samples, rather than just college graduates.

Table 19: Average cumulative full-time jobs, by years since labor market entry

			Years since labor market entry									
	Obs	Age	1	2	3	4	5	6	7	8	9	10
All Jobs	428	18.7	1.3	2.0	2.7	3.5	4.3	5.0	5.7	6.4	7.0	7.7
Type 1	428	18.9	1.3	1.7	2.2	2.8	3.6	4.3	5.0	5.7	6.3	7.0
Type 2	428	18.7	1.2	1.9	2.6	3.3	4.1	4.8	5.5	6.2	6.8	7.5
Type 3	427	19.7	1.2	1.7	2.2	2.7	3.4	4.1	4.8	5.5	6.1	6.8
Type 4	426	20.4	1.2	1.5	1.9	2.3	3.0	3.7	4.3	5.0	5.5	6.2

Notes: Each cell describes how many jobs are held, on average, by a worker by each year since labor market entry. Jobs in Type 1 exclude summer jobs. Jobs in Type 2 exclude temporary jobs. Jobs in Type 3 exclude regular long-term jobs. In Type 4, we start counting jobs after college graduation. All averages are computed using sample weights.

Table 20: Average cumulative full-time jobs by age

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
All Jobs	0.9	1.6	2.3	3.0	3.7	4.5	5.2	5.9	6.5	7.3	7.9	8.5	9.1	9.7	10.1	10.5	10.9	11.3
Type 1	0.5	0.9	1.3	1.8	2.5	3.3	4.0	4.7	5.4	6.1	6.7	7.3	7.9	8.5	9.0	9.3	9.7	10.1
Type 2	0.8	1.5	2.1	2.8	3.5	4.3	5.0	5.7	6.3	7.0	7.7	8.3	8.9	9.5	9.9	10.3	10.6	11.0
Type 3	0.8	1.5	2.1	2.8	3.5	4.3	5.0	5.7	6.3	7.0	7.7	8.3	8.9	9.5	9.9	10.3	10.6	11.0
Type 4	0.0	0.0	0.0	0.2	0.7	1.4	2.1	2.8	3.5	4.2	4.8	5.4	6.0	6.6	7.0	7.4	7.8	8.2

Notes: Each cell describes how many jobs are held, on average, by a worker by each age. Jobs in Type 1 exclude summer jobs. Jobs in Type 2 exclude temporary jobs. Jobs in Type 3 exclude regular long-term jobs. In Type 4, we start counting jobs after college graduation. All averages are computed using sample weights.

in Type 3 exclude regular long-term jobs. In Type 4, we start counting jobs after college graduation.

Our finding is broadly consistent with Light (2005), who shows that male college graduates held 4.3 jobs on average within eight years after graduation (the closest category for us is Type 4), even though we have a slightly different method of calculating the number of jobs.[21]

In Table 20, we instead calculate the number of career-contributing jobs as a function of age, as in Hall (1982). We can observe that the cumulative number of jobs before age 35 is smaller by about three if we entirely disregard the JBCC. Even if we disregard only summer jobs, the cumulative number of jobs before age 35 is smaller by more than one.

2.4 Conclusion

In this paper, we analyzed the job switching and wage growth of young workers, separately considering between the jobs experienced by workers before and after college completion. The jobs held before college completion are special in that their occupations are very different and they do not have much effect on subsequent wage growth. If we disregard these jobs, the number of career-contributing jobs that are experienced by young workers is smaller by a nontrivial amount.

[21]Our approach is different from Light (2005) in the following two ways. First, Light (2005) counts jobs held by some college plus all college graduates, while we only focus on college students graduated at age 23 or before. Second, Light (2005) starts to count jobs at the start of the first school exit that lasts at least 12 months, while in Type 4 we start to count at the year they reached 16 years of education.

Chapter 3

The Great Recession: Divide between Integrated and Less Integrated Countries

Coauthored with Dr. Guillermo Hausmann-Guil and Professor Eric van Wincoop

3.1 Introduction

There are two important features of business cycle synchronization across countries during the 2008-2009 Great Recession. The first is that synchronicity during this period was unparalleled historically. Perri and Quadrini (2018) show that business cycle correlations were much higher among industrialized countries during this period than any earlier time since 1965. [1] Remarkably, even though the origin of the recession is widely associated with the United States, the decline in GDP, investment, consumption and corporate profits were of a very similar magnitude in the rest of the world as in the United States. [2] The decline was also similar in emerging economies as in industrialized countries, and was of a similar magnitude in Europe, the US and Asia. [3]

[1] See also Imbs (2010) and Fund (2013).

[2] See Bacchetta and van Wincoop (2016).

[3] We are interested here in the unusual and sudden increase in synchronicity of business cycles during the Great Recession as opposed to trends in synchronicity over time. Regarding the latter, Bordo and Helbling

A second feature relates to the link between business cycle synchronization and economic integration. There is an existing empirical literature that finds no robust relationship between measures of trade and financial integration on the one hand and the decline in growth during the Great Recession on the other hand. [4] In this paper we confirm the absence of a robust monotonic relationship between business cycle synchronization and measures of trade and financial integration. However, we find that integration does matter beyond some threshold. When integration is sufficiently low, below a particular threshold, countries are considerably less impacted by the Great Recession. This finding is robust to introducing a wide variety of controls, different measures of crisis performance, and different subsets of countries. It holds for both trade and financial integration separately as well as for a combined index of trade and financial integration.

The paper develops a theory that accounts for these two features of business cycle synchronization during the Great Recession. It is useful to start though by pointing out that the evidence goes against most existing theories of business cycles in open economy models. In most models synchronicity occurs either because of a common shock that affects all countries or because an exogenous fundamental shock is transmitted across countries through trade and financial linkages. Regarding the former, shocks that are typically attributed to this period apply to the housing market and financial markets. Those shocks, however, originated largely in the United States rather than being common across countries. Regarding transmission of shocks, it is well known that this depends on the nature of the shocks and even perfect integration does not need to imply perfect business cycle synchronization.[5] Even when a model implies that higher trade or financial integration leads to higher business cycle synchronization, transmission of shocks across countries is significantly limited by home bias in both goods and financial markets.[6]

The theory we develop to explain the two features of business cycle synchronization during the Great Recession is based on an extension of Bacchetta and van Wincoop (2016), from

(2011) find that there has been a trend towards increased integration during most of the twentieth century, while Hirata et al. (2014) find that over the past 25 years the global component of business cycles has declined relative to local components (region and country-specific).

[4] Among many others, see Rose and Spiegel (2010), Rose and Spiegel (2011), Kamin and DeMarco (2012), Kalemli-Ozcan et al. (2013), and Fund (2013). Cecchetti et al. (2013) contain an overview of all the relevant studies.

[5] For example, a standard open economy real business cycle model with perfect integration of goods and financial markets, such as Backus et al. (1992), implies that output is negatively correlated across countries.

[6] As an example of this, Uhlig (2013) shows that under realistic financial home bias, transmission across countries of balance sheets shocks experienced by leveraged institutions is limited.

here on BvW. BvW explain the Great Recession as the result of a self-fulfilling expectations shock as opposed to an exogenous shock to fundamentals. When agents believe that income will be lower in the future, they reduce current consumption, which reduces current output and firm profits. This in turn reduces investment and therefore future output, making beliefs self-fulfilling. However, the novel aspect of BvW is not the idea of self-fulfilling expectations shocks to explain business cycles. There are many such models.[7] The novel aspect is to show that in an open economy context such self-fulfilling beliefs are necessarily coordinated across countries beyond a certain threshold of integration. This coordination occurs because their interconnectedness makes it impossible for one country to have very pessimistic beliefs about the future, while the other country has very optimistic beliefs. BvW show that partial integration is therefore sufficient to generate a perfectly synchronized decline in output across countries.

However, the model in BvW does not address the second feature of business cycle synchronization, the non-linear relationship between economic integration and business cycle synchronization seen during the Great Recession. The model consists of only two countries, so that it cannot study cross-sectional variation in the degree of economic integration. Moreover, BvW only consider trade integration and abstract from financial integration. We therefore develop a model that extends the framework of BvW to analyze the case where there is a continuum of countries, with the extent of both trade and financial integration varying across countries.

The model is able to generate equilibria that are consistent with the empirical evidence. We find that a global panic will involve all countries whose level of integration is above a certain level, while in general at most a subset of the remaining less integrated countries will panic. The relationship between integration and business cycles is therefore discontinuous as in the data. Within these two groups of countries there is no relationship between their level of integration and the drop in their output, confirming that there is no monotonic relationship between integration and output during a global panic. We also find that trade and financial integration are substitutes in the threshold level of integration, which is confirmed as well by the evidence. Finally, in an extension with country-specific productivity shocks we can explain why not all integrated countries performed worse than less integrated countries.

[7] These are generally closed economy models. Examples include Aruoba et al. (2017), Bacchetta et al. (2012), Benhabib et al. (2016), Farmer (2012a), Farmer (2012b), Heathcote and Perri (2017), Liu and Wang (2014), Mertens and Ravn (2014), Schmitt-Grohe and Uribe (2017), and Schmitt-Grohe (1997).

Such differences in performance due to country-specific shocks are unrelated to levels of integration.

Two other papers have looked at self-fulfilling beliefs in an open economy framework. Bacchetta and van Wincoop (2016) develop a two country model with self-fulfilling shifts in perceived asset price risk. Perri and Quadrini (2018) consider self-fulfilling credit shocks in a two-country setup. If the resale price of assets of firms is low, collateral is weak and it is harder to borrow. This makes it more difficult for other firms to purchase the assets of defaulting firms, which indeed leads to a low resale value of their assets. These papers differ from the framework considered here in several ways. First, these papers do not highlight the coordination of self-fulfilling beliefs under partial integration. In Perri and Quadrini (2018) there is perfect business cycle synchronization, but this is a result of perfect financial and goods market integration and occurs also with exogenous credit shocks. In Bacchetta and van Wincoop (2016), risk panics are generally not synchronized across countries under either partial or perfect integration. Second, these papers have two country models and therefore cannot consider the role of heterogeneity in financial integration in accounting for the different growth performance across countries during the Great Recession. Finally, the nature of self-fulfilling beliefs is quite different in this paper and is unrelated to asset prices or asset price risk.

Another related literature is that of complex financial networks. Some papers in this literature have shown that with limited financial interconnectedness there can be a tipping point where shocks are spread across the entire network of financial institutions.[8] But these tipping points refer to a general level of interconnectedness rather than the cross-sectional variation in interconnectedness that we will consider here. Moreover, it is much harder to tell such network stories based on a standard business cycle model with firms and households.[9]

The remainder of the paper is organized as follows. Section 2 discusses the empirical evidence on the relationship between output growth during the Great Recession and the extent of trade and financial integration. Section 3 describes the model and Section 4 analyzes the equilibria. Section 5 concludes.

[8]See for example Gai et al. (2011) or Nier et al. (2007).

[9]While one can easily imagine a financial institution being a critical node in a broader network, it is much harder to argue so for an individual household or firm, particularly on a global scale.

3.2 Empirical Evidence

We collect data for a sample of 151 countries, based on data availability. The precise sample of countries is tabulated in Table 21.[10] Our main data sources are the April 2014 World Economic Outlook (WEO) Database, and the World Development Indicators (WDI) from the World Bank Database. In addition, we get data on financial variables from the "External Wealth of Nations"dataset, constructed by Lane and Milesi-Ferretti (2007), data on the exchange rate regime from the "Shambaugh exchange rate classification" dataset, and data on the manufacturing share of GDP from the United Nations Database. Table 22 shows some descriptive statistics, together with the specific data source of each variable.

The set of countries and variables used in the regressions is similar to Lane and Milesi-Ferretti (2011). In particular, we use their same measures of integration, namely trade openness (defined as imports plus exports divided by GDP) and financial openness (defined as external assets plus external liabilities divided by GDP), both in percentage terms. We deviate from them, though, by choosing the forecast errors (the actual 2009 GDP growth rate minus the April 2008 WEO pre-crisis forecast) as our preferred measure of crisis performance. This measure, first proposed by Berkmen et al. (2012), has the advantage of controlling for other factors unrelated to the impact of the crisis that may have affected countries' growth rates during this period. Nevertheless, we use the 2009 GDP growth rate as an alternative measure of the crisis intensity in the robustness checks, with similar results.

In our main regressions, we exclude from our sample countries with a GDP per capita below a thousand 2007 dollars (poor countries), as well as countries above the 95^{th} percentile in financial openness (financial centers).[11] We exclude poor countries, both because of data quality issues and because extremely poor countries tend to rely heavily on official forms of international finance, thus being less exposed to private-sector financial flows (see Lane and Milesi-Ferretti (2011)). For these countries, high values of financial openness can be quite misleading. Similarly, we exclude financial centers because their extreme values of financial

[10] We also had data available for Armenia, Equatorial Guinea and Luxembourg, but we decided to exclude these countries from all our regressions. We excluded Armenia because, in addition to being one of the most affected countries by the crisis, it is more integrated than what our measures of economic integration reflect due to remittances. We excluded Equatorial Guinea for overall problems with data quality (see Lane and Milesi-Ferretti (2011)), and Luxembourg because of its extreme value for financial openness, which is well known to be associated with measurement error. Including these three countries does not substantially change our main results, though.

[11] These include Mauritius, Iceland, Bahrain, Switzerland, Hong Kong, Ireland and Singapore.

Table 21: List of Countries

ALB	Albania	GEO	Georgia	NGA	Nigeria
DZA	Algeria	DEU	Germany	OMN	Oman
AGO	Angola	GHA	Ghana	PAK	Pakistan
ATG	Antigua and Barbuda	GRC	Greece	PAN	Panama
ARG	Argentina	GRD	Grenada	PRY	Paraguay
AUS	Australia	GTM	Guatemala	PER	Peru
AUT	Austria	GIN	Guinea	PHL	Philippines
AZE	Azerbaijan	GNB	Guinea-Bissau	POL	Poland
BHR	Bahrain	HTI	Haiti	PRT	Portugal
BGD	Bangladesh	HND	Honduras	QAT	Qatar
BLR	Belarus	HKG	Hong Kong SAR	COG	Republic of Congo
BEL	Belgium	HUN	Hungary	ROM	Romania
BLZ	Belize	ISL	Iceland	RUS	Russia
BEN	Benin	IND	India	WSM	Samoa
BTN	Bhutan	IDN	Indonesia	SAU	Saudi Arabia
BOL	Bolivia	IRL	Ireland	SEN	Senegal
BWA	Botswana	IRN	Islamic Republic of Iran	SYC	Seychelles
BRA	Brazil	ISR	Israel	SLE	Sierra Leone
BRN	Brunei Darussalam	ITA	Italy	SGP	Singapore
BGR	Bulgaria	JAM	Jamaica	SVK	Slovak Republic
BFA	Burkina Faso	JPN	Japan	SVN	Slovenia
BDI	Burundi	JOR	Jordan	ZAF	South Africa
CPV	Cabo Verde	KAZ	Kazakhstan	ESP	Spain
CMR	Cameroon	KEN	Kenya	LKA	Sri Lanka
CAN	Canada	KOR	Korea	KNA	St. Kitts and Nevis
CAF	Central African Republic	KWT	Kuwait	LCA	St. Lucia
TCD	Chad	KGZ	Kyrgyz Republic	VCT	St. Vincent and the Grenadines
CHL	Chile	LAO	Lao P.D.R.	SDN	Sudan
CHN	China	LVA	Latvia	SWZ	Swaziland
COL	Colombia	LBN	Lebanon	SWE	Sweden
COM	Comoros	LSO	Lesotho	CHE	Switzerland
CRI	Costa Rica	LBY	Libya	STP	São Tomé and Príncipe
HRV	Croatia	LTU	Lithuania	TJK	Tajikistan
CYP	Cyprus	MDG	Madagascar	TZA	Tanzania
CZE	Czech Republic	MWI	Malawi	THA	Thailand
CIV	Côte d'Ivoire	MYS	Malaysia	GMB	The Gambia
ZAR	Democratic Republic of the Congo	MDV	Maldives	TGO	Togo
DNK	Denmark	MLI	Mali	TON	Tonga
DJI	Djibouti	MUS	Mauritius	TTO	Trinidad and Tobago
DMA	Dominica	MEX	Mexico	TUN	Tunisia
DOM	Dominican Republic	MDA	Moldova	TUR	Turkey
EGY	Egypt	MNG	Mongolia	UGA	Uganda
SLV	El Salvador	MAR	Morocco	UKR	Ukraine
EST	Estonia	MOZ	Mozambique	ARE	United Arab Emirates
ETH	Ethiopia	NAM	Namibia	GBR	United Kingdom
MKD	FYR Macedonia	NPL	Nepal	USA	United States
FJI	Fiji	NLD	Netherlands	URY	Uruguay
FIN	Finland	NZL	New Zealand	VUT	Vanuatu
FRA	France	NIC	Nicaragua	VEN	Venezuela
GAB	Gabon	NER	Niger	VNM	Vietnam
				ZMB	Zambia

Table 22: Descriptive statistics and data source

Variable	Mean	Std. Dev.	Min	Max	Source
Forecast error 09	-5.11	4.38	-20.35	5.80	WEO April 2008 and April 2014
GDP growth 09	-0.15	5.14	-17.70	11.96	WEO April 2014
GDP growth trend 96/07	4.43	2.28	0.70	15.29	WEO April 2014
Avrg. GDP growth 04/07	5.69	3.17	-0.71	24.03	WEO April 2014
Trade openness	92.95	50.55	25.21	398.66	World Bank WDI
Financial openness	290.33	418.86	47.75	2604.66	Lane and Milesi-Ferretti
GDPpc (thousands of 2007 dollars)	12.11	16.41	0.17	69.17	WEO April 2014
GDP (billions of 2007 dollars)	365.40	1334.82	0.14	14480.35	WEO April 2014
Population (in millions)	41.45	145.84	0.05	1321.29	WEO April 2014
Manufacturing share	13.55	6.91	1.99	40.78	United Nations database
Current account (% of GDP)	-2.34	13.02	-31.91	47.82	WEO April 2014
Net foreign assets (% of GDP)	-15.95	161.56	-201.39	1618.02	Lane and Milesi-Ferretti
Reserves minus gold (% of GDP)	19.26	17.92	0.21	117.31	Lane and Milesi-Ferretti
Private credit growth 04/07 (% of GDP)	33.39	45.93	-41.18	287.91	World Bank WDI

openness tend to reflect their role as financial intermediaries rather than true integration. We have 34 countries classified as poor and 7 countries classified as financial centers, thus leaving us with a benchmark sample of 110 countries. We will consider specifications including these subsets of countries in our robustness analysis.

We follow the empirical literature by regressing the forecast errors on several 2007 pre-crisis variables, as a way to identify "initial conditions" that help to explain the slowdown during the crisis. These variables include our two measures of economic integration, plus the following controls: the average GDP growth rate from 2004 to 2007; the trend growth rate (proxied by the average GDP growth rate from 1996 to 2007); the growth in the ratio of private credit to GDP over the period 2004-07; the share of the manufacturing sector in GDP (in percentage terms); the current account to GDP ratio; the net foreign asset position (as a percentage of GDP); the external reserves to GDP ratio; the log of country population (in millions); the level of GDP per capita (in thousands of 2007 dollars); the level of GDP (in billions of dollars); a dummy that equals 1 if the country had a de facto fixed exchange regime during 2007; and an oil dummy.[12] All these variables have been widely used in the literature examining what factors played a role in the cross country variation of business cycles during the Great Recession.[13]

[12]We define as oil exporters the 2007 OPEC members, plus the following countries: Azerbaijan, Belize, Brunei, Chad, Gabon, Kazakhstan, Republic of Congo, Russia, Sudan, and Trinidad and Tobago.

[13]See Cecchetti et al. (2013) for a summary of selected studies examining crisis impact, their main explanatory variables, and their findings.

In addition to this, we consider different integration dummies as we are mainly interested in whether the level of economic integration matters in a non-continuous or monotone way. We first experiment with simple trade and financial dummies, which take a value of 1 if the level of trade/financial openness is above some percentile level, and zero otherwise. We also consider a joint trade and financial integration dummy, constructed as follows. We first take a linear combination of our two measures of integration:

$$Integration_i = \alpha \; trade_i + (1-\alpha) \; financial_i, \tag{3.1}$$

where $trade_i$ and $financial_i$ are our two measures of trade and financial openness of country i, and $\alpha \in [0,1]$ is a parameter to be chosen. The joint dummy then equals 1 when the combined integration measure is above some cutoff γ, and zero otherwise.

Since we have a priori no idea about the proper values for α and γ, we follow the Threshold Estimation literature and estimate them by means of Maximum Likelihood (MLE), in a way similar to Hansen (2000). Specifically, we want to estimate the following model:

$$y_i = \theta_0 + \beta' x_i + e_i, \qquad q_i(\alpha) \leq \gamma$$

$$y_i = \theta_1 + \beta' x_i + e_i, \qquad q_i(\alpha) > \gamma$$

where y_i is a measure of the crisis performance, x_i is our vector of pre-crisis controls, β' is a vector of coefficients, θ_0 and θ_1 are the intercepts, $q_i(\alpha)$ is our combined measure of integration described above, and e_i is an error term. Thus, in this model we allow the intercept θ to change when the threshold variable q is above some unknown cutoff γ, which is assumed to be restricted to a bounded set $[\underline{\gamma}, \overline{\gamma}] = \Gamma$. Moreover, the threshold variable depends on some unknown parameter α.[14] To write the model in a single equation, define the dummy variable

$$d_i(\alpha, \gamma) = \{q_i(\alpha) > \gamma\}$$

where $\{\cdot\}$ denotes the indicator function. Then, the model above can be rewritten as

$$y_i = \theta_0 + \eta d_i(\alpha, \gamma) + \beta' x_i + e_i,$$

[14]The procedure described here also applies to the simpler case with a trade or a financial dummy. One just has to set either $\alpha = 1$ or $\alpha = 0$.

where η is the dummy coefficient. The regression parameters are $(\beta', \theta_0, \eta, \alpha, \gamma)$, and the natural estimator is least squares (LS), which is also the MLE if one assumes that e_i is iid $N(0, \sigma^2)$. By definition, the LS estimators $(\widehat{\beta}', \widehat{\theta}_0, \widehat{\eta}, \widehat{\alpha}, \widehat{\gamma})$ jointly minimize the sum of the squared errors S_n. To compute these estimators, we proceed as follows. First, we choose some values for $\alpha \in A$ and $\gamma \in \Gamma_n$, where A is an evenly spaced grid such that $0 = \alpha_0 < \alpha_1 < ... < \alpha_J = 1$, and $\Gamma_n = \Gamma \cap \{q_{(1)}, ..., q_{(n)}\}$ where $q_{(j)}$ denotes the jth percentile of the sample $\{q_1, ..., q_n\}$.[15] Conditional on these values, we run an OLS regression and obtain the sum of squared errors $S_n(\alpha, \gamma)$, where we just make explicit that S_n depends upon α and γ. Then, the MLE estimator $(\widehat{\alpha}, \widehat{\gamma})$ are those values for α and γ that minimize $S_n(\alpha, \gamma)$, or more formally,

$$(\widehat{\alpha}, \widehat{\gamma}) = \underset{\alpha \in A, \gamma \in \Gamma_n}{\arg\min} \; S_n(\alpha, \gamma)$$

In practice, this reduces to choose the regression in the $A \times \Gamma_n$ space for which the sum of the squared residuals is the smallest. Finally, we can test whether the estimated threshold is significant or not just by checking the p-value of $\widehat{\eta}$. After following this procedure for different subsets of the controls, we consistently find point estimates of $\widehat{\alpha} = 0.10$ and $\widehat{\gamma} = 137.61$, which corresponds to the 37^{th} percentile of the combined integration variable.[16]

Figure 15 provides a visual illustration with raw data. In this picture, we plot two subsets of countries in the trade-financial openness space. Specifically, we distinguish between good performers (countries with a forecast error higher than the mean plus $\frac{1}{2}$ of the standard deviation) and bad performers (with a forecast error lower than the mean minus $\frac{1}{2}$ of the standard deviation).[17] The plotted line consists of all the values in the trade-financial space for which the combined integration variable, with $\alpha = 0.10$, takes a value of 137.61. We refer to the region above the line as the integrated region, and to the region below as the not-integrated region.

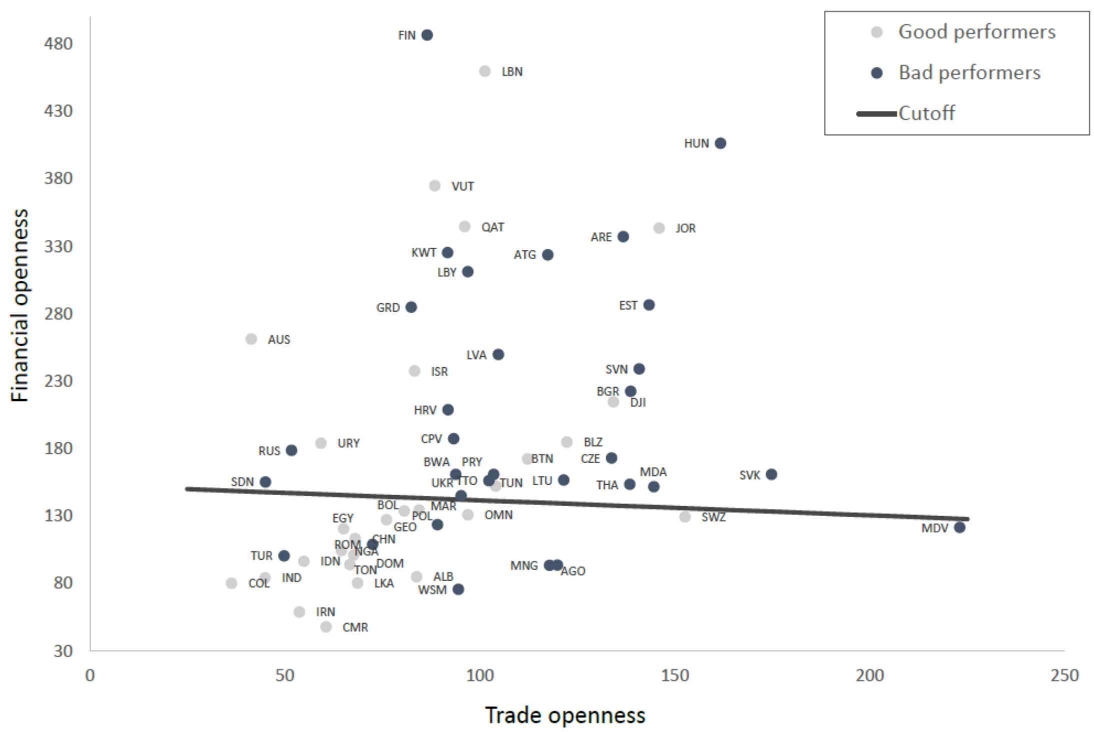
Two facts are immediate from Figure 15. First, we have both good and bad performers in each region. Second, the ratio of bad performers to good performers is much higher in the integrated region than in the not-integrated one (2.18 in the former, 0.41 in the latter). Finally, a simple regression of the forecast error on the joint dummy plus the logs of trade and

[15] In the numerical search, we use .05 increments for A.

[16] During the search process, we sometimes found another local minimum for a much higher value of γ around the 70^{th} percentile, but this finding was not robust to different subsets of the controls.

[17] Recall that in general the forecast error are negative, meaning that countries tended to perform worse in the crisis than expected. Thus, a more negative forecast error implies a worse crisis performance.

Figure 15: Good and Bad Performers in the TradeFinancial Space



financial openness gives a coefficient of -4.09 on the joint dummy with a p-value well below 0.01. It means that, on average, countries in the integrated region suffered an unexpected GDP growth downturn around 4 percentage points compared to the others. These initial results may look encouraging, but it remains to be seen whether they still hold after a more formal econometric analysis, introducing various controls, to which we turn next.

3.2.1 Regression results

Without integration dummies

Table 23 reports the results from regressions without integration dummies included. In Column 1 we regress the forecast error on the logs of trade and financial openness and the controls discussed above. We observe that neither the trade openness nor the financial openness variables are significant. Column 2 runs the same regression but with 2009 GDP growth as the dependent variable. Since we include both the growth trend and the pre-crisis average GDP growth in the regressors, this specification is the same as one where the dependent variable is the change in the growth rate relative to trend or relative to the period 2004-07. As before, both integration coefficients are insignificant.

Column 3 includes the financial centers and column 4 includes the poor countries. The inclusion of these subsets of countries makes trade openness significant at the 10% level, but financial openness remains insignificant. Columns 5 and 6 replicates our first two columns but including all the countries in our sample. In column 5 trade openness now becomes significant at the 5% level, but this is not a robust finding as it loses significance once we change our measure of crisis performance in column 6. Overall, we have little success finding any robust relationship between pre-crisis variables and measures of crisis performance, in line with the previous crisis literature.[18]

With integration dummies

In Table 24 we experiment with the different integration dummies discussed before. Column 1 regresses the forecast errors on all the explanatory variables plus a trade dummy that equals one when the value of trade openness is above the 42^{th} percentile. The coefficient of this dummy alone is quite negative (-3.01) and significant at the 5% level. The coefficients

[18] See for example Rose and Spiegel (2011).

Table 23: Regressions without integration dummies

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Forecast error	GDP growth 09	Forecast error	Forecast error	Forecast error	GDP growth 09
Log(Trade openness)	-1.774	-0.589	-1.906*	-2.080*	-2.301**	-1.660
	(1.1057)	(1.1415)	(1.0700)	(1.0962)	(1.0032)	(1.0556)
Log(Financial openness)	-0.679	-1.116	0.125	0.058	0.743	0.848
	(1.1011)	(1.1730)	(0.9351)	(0.9542)	(0.8433)	(0.9990)
Current account	0.044	0.013	0.027	0.109**	0.081*	0.090*
	(0.0734)	(0.0879)	(0.0546)	(0.0535)	(0.0455)	(0.0524)
Net foreign assets	-0.002	0.002	0.001	-0.007	-0.000	0.001
	(0.0068)	(0.0079)	(0.0017)	(0.0057)	(0.0017)	(0.0019)
Reserves	-0.021	-0.014	-0.012	-0.025	-0.021	-0.024
	(0.0333)	(0.0347)	(0.0316)	(0.0301)	(0.0295)	(0.0292)
Credit growth 04/07	-0.036**	-0.046**	-0.035**	-0.018*	-0.018*	-0.017
	(0.0172)	(0.0193)	(0.0169)	(0.0102)	(0.0106)	(0.0105)
Manufacturing share	-0.069	-0.151	-0.036	-0.085	-0.067	-0.150**
	(0.0869)	(0.0938)	(0.0740)	(0.0708)	(0.0613)	(0.0653)
Growth trend	0.042	0.396	0.062	0.158	0.169	0.440**
	(0.2597)	(0.2386)	(0.2507)	(0.2762)	(0.2589)	(0.2186)
Avrg. GDP growth 04/07	-0.187	0.108	-0.157	-0.272	-0.244	0.011
	(0.2061)	(0.2265)	(0.1978)	(0.2010)	(0.1891)	(0.2014)
Peg dummy	0.439	-0.087	-0.024	0.639	0.323	-0.130
	(0.8667)	(0.8715)	(0.8309)	(0.7240)	(0.7093)	(0.7591)
Oil dummy	-0.665	0.649	-0.490	-1.510	-1.658	-0.869
	(1.5216)	(1.6488)	(1.4453)	(1.2915)	(1.2445)	(1.3775)
GDPpc	-0.038	-0.069	-0.039	-0.082	-0.088*	-0.149**
	(0.0589)	(0.0730)	(0.0498)	(0.0557)	(0.0463)	(0.0625)
GDP	-0.000	-0.000	-0.000	0.000	-0.000	-0.000
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Log(Population)	0.203	0.512	0.151	0.129	0.122	0.392
	(0.3192)	(0.3543)	(0.2846)	(0.2806)	(0.2514)	(0.2785)
Constant	6.172	1.679	2.839	5.613	3.177	-0.115
	(9.6579)	(10.7313)	(8.0674)	(8.5209)	(7.1908)	(8.4511)
Observations	110	110	117	144	151	151
R-squared	0.232	0.319	0.214	0.235	0.213	0.319

Robust standard errors in parentheses

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

of trade and financial openness are still insignificant, and the remaining controls follow the same pattern as in Table 23. In column 2 we run the same regression, but this time with a financial dummy that equals one if financial openness is above the 36^{th} percentile instead. The coefficient of this financial dummy (-4.54) is even lower than the trade one, and strongly significant.

Column 3 includes the joint dummy in the regression. It has a coefficient of -4.72 that is significant at all the conventional levels. It means that, everything else equal, the forecast errors of countries above the 37^{th} percentile in the combined integration measure were on average 4.72 percentage points lower. Given that the average forecast error was around -5, this represents a highly sizable effect. Moreover, the subset of countries for which this dummy equals 1 comprises high share of World's GDP, as it includes the U.S., Japan, and most of the E.U. countries.[19]

3.2.2 Robustness checks

In this subsection we choose the joint dummy as our most preferred measure of a non-continuous effect of integration on crisis performance, and run several robustness tests on it.

First, in Table 26 we explore the sensitivity of the dummy to different choices of α and percentiles' cutoffs. In this table, different rows correspond to different values of α, ranging from 0 to 1, and different columns correspond to different choices of the percentile cutoff, ranging from the 19^{th} percentile of the combined integration variable to the 45^{th} percentile. The numerical entries in the table are the coefficient values of joint dummies from regressions with the same specification as in column 3 of Table 24. Bold numbers mean that the dummy is significant at the 10% level at least. We find that coefficients between the 19^{th} and the 43^{th} percentile tend to be significant at the 10% level, and in most cases (specially around our benchmark joint dummy with $\alpha = 0.10$ and the 37^{th} cutoff) we achieve significance at the 5% or 1% level. These results suggest that the discontinuous effect of integration on crisis performance is not particularly sensitive to different choices of the parameter values or percentile cutoffs.

Next, in Table 27 we run additional robustness checks for alternative measures of crisis

[19]Table 25 provides the specific list of countries for which the joint dummy equals 0 (the less integrated countries).

Table 24: Regressions with integration dummies

	(1)	(2)	(3)
VARIABLES	Forecast error	Forecast error	Forecast error
Trade dummy	-3.011**		
	(1.3572)		
Financial dummy		-4.541***	
		(1.1794)	
Joint dummy			-4.716***
			(1.2050)
Log(Trade openness)	0.779	-1.973*	-1.458
	(1.5560)	(1.0923)	(1.0370)
Log(Financial openness)	-0.408	2.019	1.963
	(1.1011)	(1.2854)	(1.2686)
Current account	0.054	0.036	0.031
	(0.0720)	(0.0731)	(0.0737)
Net foreign assets	-0.002	-0.005	-0.005
	(0.0069)	(0.0067)	(0.0068)
Reserves	-0.019	-0.004	-0.004
	(0.0327)	(0.0321)	(0.0321)
Credit growth 04/07	-0.035**	-0.038**	-0.038**
	(0.0155)	(0.0163)	(0.0161)
Manufacturing share	-0.060	-0.044	-0.055
	(0.0830)	(0.0711)	(0.0706)
Growth trend	-0.032	0.079	0.120
	(0.2246)	(0.2069)	(0.2102)
Avrg. GDP growth 04/07	-0.100	-0.169	-0.215
	(0.1844)	(0.1912)	(0.1923)
Peg dummy	0.484	0.356	0.164
	(0.8470)	(0.8264)	(0.8270)
Oil dummy	-0.376	-0.213	-0.065
	(1.5516)	(1.4742)	(1.4753)
GDPpc	-0.040	-0.042	-0.036
	(0.0589)	(0.0596)	(0.0599)
GDP	0.000	0.000	0.000
	(0.0002)	(0.0002)	(0.0002)
Log(Population)	0.035	0.060	0.082
	(0.3409)	(0.2898)	(0.2888)
Constant	-2.708	-2.926	-4.987
	(8.8620)	(9.2963)	(9.3826)
Observations	110	110	110
R-squared	0.265	0.325	0.330

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 25: List of less integrated countries

Albania	India
Algeria	Indonesia
Angola	Islamic Republic of Iran
Argentina	Korea
Azerbaijan	Maldives
Belarus	Mexico
Bolivia	Mongolia
Brazil	Morocco
Cameroon	Nigeria
China	Oman
Colombia	Peru
Costa Rica	Philippines
Dominican Republic	Poland
Egypt	Romania
El Salvador	Samoa
Fiji	Sri Lanka
Gabon	Swaziland
Georgia	Tonga
Ghana	Turkey
Guatemala	Venezuela
Honduras	

Table 26: Sensitivity of the Integration Dummy

PERCENTILE	19	21	23	25	27	29	31	33	35	37	39	41	43	45
ALPHA														
0	**-2.72**	**-2.76**	**-2.65**	**-2.56**	**-2.36**	**-2.28**	**-2.76**	**-3.59**	**-4.35**	**-3.69**	**-3.90**	**-3.38**	**-2.51**	-0.61
0.05	**-2.64**	**-2.76**	-2.12	**-2.56**	**-2.45**	**-2.28**	**-2.76**	**-3.59**	**-4.35**	**-3.69**	**-3.90**	**-3.17**	**-2.51**	-0.61
0.1	**-2.64**	**-2.76**	-2.12	**-2.56**	**-2.45**	**-2.28**	**-2.54**	**-3.29**	**-3.91**	**-4.72**	**-3.90**	**-3.29**	**-2.51**	-0.61
0.15	**-2.64**	**-2.23**	**-2.68**	**-2.31**	**-2.45**	**-2.25**	**-2.73**	**-3.09**	**-3.64**	**-4.32**	**-3.90**	**-3.29**	-1.87	-0.61
0.2	**-2.64**	**-2.23**	**-2.49**	**-2.31**	**-2.45**	**-2.25**	**-2.73**	**-3.09**	**-3.64**	**-3.35**	**-3.13**	**-3.29**	-2.10	-0.37
0.25	**-2.99**	**-2.52**	**-2.49**	**-2.31**	**-2.45**	**-2.52**	**-2.98**	**-3.06**	**-3.64**	**-3.35**	**-3.13**	-2.01	-1.57	-1.23
0.3	**-3.17**	**-2.93**	**-2.49**	**-2.17**	**-2.45**	**-2.52**	**-2.98**	**-3.48**	**-3.41**	**-3.35**	**-3.13**	-2.04	-1.18	-0.64
0.35	**-3.17**	**-2.93**	**-2.60**	**-2.17**	**-2.45**	**-2.49**	**-2.71**	**-2.84**	**-3.41**	**-3.35**	-1.51	-0.87	-1.18	-1.07
0.4	**-3.17**	**-2.93**	**-2.60**	**-2.46**	-2.22	**-2.51**	**-2.23**	**-2.84**	**-3.41**	**-3.35**	-1.51	-1.29	-0.74	0.26
0.45	**-3.17**	**-2.93**	**-3.17**	**-2.90**	**-2.49**	-2.01	**-2.23**	**-2.84**	**-3.41**	**-2.62**	-1.17	-1.38	-0.74	0.26
0.5	**-3.36**	**-2.93**	**-3.17**	**-2.95**	**-2.46**	**-2.30**	**-2.26**	**-2.84**	**-3.41**	**-3.02**	-2.25	-1.38	-0.74	0.26
0.55	**-3.41**	**-2.86**	**-2.63**	**-2.95**	**-2.46**	**-3.08**	**-2.73**	**-2.78**	**-2.81**	-2.01	-2.25	-0.58	-0.25	-0.07
0.6	**-3.41**	**-2.86**	**-2.63**	**-2.34**	**-2.44**	**-2.25**	-1.76	**-2.30**	-1.98	-2.16	-2.36	-0.58	-0.70	0.35
0.65	**-3.68**	**-3.06**	-2.16	**-2.34**	-1.71	-2.04	-1.87	**-2.38**	**-2.41**	**-2.82**	**-2.70**	-1.36	-0.54	-1.19
0.7	**-2.74**	**-3.00**	-2.16	-1.41	-1.71	**-2.41**	**-2.71**	-2.15	**-2.22**	**-2.69**	**-3.33**	**-2.28**	-2.23	-1.19
0.75	**-2.16**	-1.54	-1.73	-1.41	-1.77	-1.96	**-2.38**	**-3.21**	**-3.15**	**-2.90**	**-3.04**	**-2.24**	-1.66	-1.21
0.8	**-2.16**	-1.34	-0.66	-2.09	**-2.63**	**-2.84**	**-2.77**	**-3.05**	**-3.47**	**-2.90**	**-2.65**	-1.91	-0.91	-1.02
0.85	-0.58	-1.65	**-2.05**	-1.39	-1.48	**-2.82**	**-3.42**	**-2.88**	**-3.34**	**-3.12**	**-2.95**	**-2.64**	-1.67	-0.88
0.9	-0.14	-1.27	**-2.05**	-1.72	-1.57	-1.54	**-2.74**	**-3.06**	**-2.96**	**-3.42**	**-3.12**	**-2.51**	-1.72	-1.08
0.95	0.00	-0.26	-1.32	-1.88	-1.81	-1.64	-1.32	-1.69	-2.09	**-3.24**	**-3.76**	**-4.13**	**-2.77**	-2.00
1	0.59	0.27	0.36	0.60	-0.83	-1.38	-1.87	-1.23	-1.26	-2.13	-1.30	**-2.56**	**-2.50**	-2.33

performance and different subsets of countries. Here, column 1 simply replicates our results from column 3 in Table 24, just for comparison purposes. In column 2 we change our measure of crisis performance and use the 2009 GDP growth as our dependent variable. As we see, the magnitude of the dummy coefficient (-4.41) is similar to column 1, and it is also significant at all the conventional levels.

In column 3 we recover the forecast error as our dependent variable and explore whether extreme outcomes in the forecast errors might be driving our results by excluding countries with forecast errors below the 5^{th} percentile. In this case, the coefficient takes a value of -2.89, higher than in column 1 but still significant at the 1% level. Columns 4 and 5 include the financial centers and the poor countries. In both cases the coefficient on the dummy is higher than in column 1, but they remain strongly significant. In columns 6 and 7 we include all the countries in our sample. With the forecast errors as the dependent variable, we still achieve significance at the 1% level and a coefficient of -3.46, and with the 2009 GDP growth we achieve significance at the 5% level and a coefficient of -2.79. Finally, in the last column we replace the joint dummy with the integration dummy computed based on the

Table 27: Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Forecast error	GDP growth 09	Forecast error	Forecast error	Forecast error	Forecast error	GDP growth 09	Forecast error
Joint dummy	-4.716***	-4.413***	-2.895***	-4.454***	-3.714***	-3.457***	-2.792**	
	(1.2050)	(1.2721)	(0.9886)	(1.0596)	(1.1579)	(1.0382)	(1.1807)	
Principal component dummy								-3.415***
								(1.2599)
Log(Trade openness)	-1.458	-0.294	-1.588	-1.716*	-2.057*	-2.310**	-1.667	0.604
	(1.0370)	(1.1670)	(0.9591)	(0.9934)	(1.0760)	(0.9952)	(1.0973)	(1.3252)
Log(Financial openness)	1.963	1.357	1.500	1.803*	2.305*	2.420**	2.203*	0.092
	(1.2686)	(1.3848)	(1.1052)	(1.0062)	(1.2180)	(1.0478)	(1.2796)	(1.1109)
Current account	0.031	0.000	-0.034	0.006	0.113**	0.076*	0.086*	0.057
	(0.0737)	(0.0884)	(0.0648)	(0.0535)	(0.0531)	(0.0445)	(0.0516)	(0.0709)
Net foreign assets	-0.005	-0.001	-0.001	-0.001	-0.011*	-0.003	-0.001	-0.003
	(0.0068)	(0.0080)	(0.0062)	(0.0019)	(0.0059)	(0.0021)	(0.0024)	(0.0066)
Reserves	-0.004	0.002	0.007	-0.004	-0.016	-0.018	-0.021	-0.026
	(0.0321)	(0.0333)	(0.0297)	(0.0281)	(0.0282)	(0.0266)	(0.0272)	(0.0316)
Credit growth 04/07	-0.038**	-0.048***	-0.029**	-0.040**	-0.019*	-0.019*	-0.018	-0.036**
	(0.0161)	(0.0183)	(0.0143)	(0.0157)	(0.0101)	(0.0107)	(0.0107)	(0.0152)
Manufacturing share	-0.055	-0.138*	-0.032	-0.039	-0.078	-0.060	-0.143**	-0.080
	(0.0706)	(0.0806)	(0.0617)	(0.0601)	(0.0626)	(0.0535)	(0.0610)	(0.0870)
Growth trend	0.120	0.469**	0.069	0.102	0.166	0.158	0.431**	0.001
	(0.2102)	(0.2252)	(0.2078)	(0.2031)	(0.2352)	(0.2216)	(0.2079)	(0.2516)
Avrg. GDP growth 04/07	-0.215	0.082	-0.046	-0.197	-0.265	-0.254	0.003	-0.121
	(0.1923)	(0.2266)	(0.1714)	(0.1857)	(0.1906)	(0.1802)	(0.2056)	(0.1975)
Peg dummy	0.164	-0.344	0.805	-0.095	0.454	0.165	-0.257	0.435
	(0.8270)	(0.8410)	(0.7240)	(0.7663)	(0.7030)	(0.6885)	(0.7590)	(0.8516)
Oil dummy	-0.065	1.210	0.085	0.070	-1.203	-1.252	-0.541	-0.681
	(1.4753)	(1.6049)	(1.2201)	(1.3980)	(1.2171)	(1.1742)	(1.3339)	(1.5382)
GDPpc	-0.036	-0.067	-0.042	-0.037	-0.086	-0.098*	-0.157**	-0.038
	(0.0599)	(0.0744)	(0.0496)	(0.0519)	(0.0584)	(0.0503)	(0.0672)	(0.0672)
GDP	0.000	-0.000	0.000	0.000	0.000	0.000	-0.000	0.000
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Log(Population)	0.082	0.398	0.161	0.038	0.045	0.015	0.306	0.075
	(0.2888)	(0.3288)	(0.2863)	(0.2552)	(0.2621)	(0.2343)	(0.2693)	(0.3069)
Constant	-4.987	-8.765	-5.614	-2.488	-2.932	-1.855	-4.180	-4.092
	(9.3826)	(10.6979)	(8.8354)	(7.9585)	(8.5642)	(7.4135)	(9.1567)	(8.9662)
Observations	110	110	103	117	144	151	151	110
R-squared	0.330	0.383	0.240	0.326	0.294	0.278	0.349	0.273

Robust standard errors in parentheses

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

principal component of the trade and financial integration variables. This is another way of combining the two instead of the linear aggregate that we have used. The results are again very similar. The threshold now occurs at the 31st percentile. The integration dummy is again substantial and highly significant.

Additionally, we tested whether our integration dummy might just be capturing some non-linear, but still continuous effect by including different combinations of second and higher order terms of trade and financial openness. The results (not reported) indicate that this is not the case, as all the higher order terms are insignificant whereas the dummy still shows a strong and statistical significant effect. If anything, the coefficient on the dummy decreases. We also tried to control for trade linkages with the US using a measure analogous to the overall trade openness, but it did not affect our results. We experimented with different subsets of the controls as well. The coefficients on trade and financial openness may or may not become significant, depending on the specification, but we consistently find that the integration dummy is significant at the 5% level at least, and in most cases with a coefficient below -3.[20]

Finally, we turn our attention to the role of households' expectations during the Great Recession. In our theory, a coordinated self-fulfilling shift in expectations among countries in the integrated region is the key driver of a global panic. One implication of this theoretical result is a discontinuity in the growth performance across countries, which we have already documented. But we can also test whether there was a significant difference in expectations of integrated versus less integrated countries. We do so by using a measure of consumer confidence. To perform this test, we collect cross-country data from the Nielsen's Global Consumer Confidence Trend Tracker, an index whose value is 100 if consumer confidence is neutral, below 100 if pessimistic and above 100 if optimistic. The data are quarterly and available for 43 of the countries in our sample, of which we classify 32 as integrated and 11 as less integrated using our previous results.[21] We take the difference between the index in Q3 of 2008 and Q1 of 2007 and regress this measure on the integration dummy in order to obtain the average difference between the two groups and see if this difference is statistically significant. We find that the drop in confidence for the integrated countries more than doubles the drop for the less integrated: 15.06 against 7.09, with an average difference of 7.97 that is statistically significant at the 5% level (p-value of 0.024).

[20] We also run regressions excluding the oil exporters, but it did not affect our results.
[21] The data can be found at http://viz.nielsen.com/consumerconfidence/.

In summary, the empirical evidence presented here suggests that there was indeed a strong, non-continuous effect of trade and financial integration on crisis performance during the Great Recession. This effect is robust to the inclusion of a variety of controls, different parameter values or percentile cutoffs, different measures of crisis performance, and different subsets of countries. We now turn to a model aimed at explaining these empirical findings.

3.3 Model Description

There are different modeling approaches one could adopt to illustrate the role of trade and financial integration heterogeneity in self-fulfilling business cycles. However, since the empirical evidence we aim to shed light on relates specifically to the Great Recession, we chose to extend the BvW setup as it connects well to the Great Recession along various dimensions. First, the model highlights particular vulnerabilities to a global panic that were in place at the time. One such vulnerability is tight credit, which plays a key role in the model. Another is limited flexibility of central banks as we were close to the ZLB. Finally, increased trade and financial integration in previous decades is a key source of vulnerability to global panics in the model. BvW show that if we relax such vulnerabilities, a global panic equilibrium would not exist. Second, a sharp drop in profits during a panic is a key ingredient of the model, which together with the tight credit drives the results. As BvW show, there was indeed a very steep synchronized global decline in profits during the Great Recession. Finally, the self-fulfilling expectation shock in the model leads to a sharp drop in demand. This is consistent with micro evidence that firms were affected more by a sudden drop in demand than sudden reduced access to credit (e.g. Kahle and Stulz (2013), Nguyen and Qian (2014)).[22]

The model has two periods and a continuum of countries distributed uniformly on the unit square. We will first describe households, firms, central banks and market clearing conditions. The entire model is then summarized in a condensed form that is used in the next section to analyze the equilibria. The model has a New Keynesian flavor in the sense that nominal wages are determined at the start of each period and are sticky within a period. This feature, together with a potential sunspot shock during period 1 that can generate self-fulfilling shifts in expectations, may lead to involuntary unemployment in the first period.[23]

[22]Tight credit is a parameter of the model. There is no shock to credit in the model.

[23]This is a small deviation from BvW, who introduce nominal rigidities through sticky prices. This makes

Some words about notation are in order before describing the model. Countries are heterogeneous in two dimensions, trade and financial integration. Trade integration will be indicated by a country-specific parameter ψ_i, with $i \in [0,1]$. Financial integration will be indicated by a country-specific parameter ϕ_k with $k \in [0,1]$. Thus country (i,k) has parameters ψ_i and ϕ_k. When dealing with integrals, j will refer to the trade dimension and l to the financial dimension.

3.3.1 Households

Utility of households in country (i,k) is

$$\frac{\left(c_1^{ik}\right)^{1-\lambda}}{1-\lambda} + \beta \frac{\left(c_2^{ik}\right)^{1-\lambda}}{1-\lambda} \tag{3.2}$$

where c_t^{ik} is the period t consumption index:

$$c_t^{ik} = \left(\frac{c_{ik,t}^{ik}}{\psi_i}\right)^{\psi_i} \left(\frac{c_{F,t}^{ik}}{1-\psi_i}\right)^{1-\psi_i} \tag{3.3}$$

where $c_{ik,t}^{ik}$ is an index of country (i,k) goods consumed by country (i,k) residents and $c_{F,t}^{ik}$ is an index of foreign goods consumed by country (i,k) residents:

$$ln\left(c_{F,t}^{ik}\right) = \int \int_0^1 \frac{1-\psi_j}{1-\bar{\psi}} \left(ln\left(c_{jl,t}^{ik}\right) - ln\left(\frac{1-\psi_j}{1-\bar{\psi}}\right)\right) djdl \tag{3.4}$$

Here $\bar{\psi} = \int_0^1 \psi_j dj$ and

$$c_{jl,t}^{ik} = \left(\int_0^1 [c_{jl,t}^{ik}(m)]^{\frac{\sigma-1}{\sigma}} dm\right)^{\frac{\sigma}{\sigma-1}} \tag{3.5}$$

is an index of country (j,l) goods consumed by country (i,k) residents, with $c_{jl,t}^{ik}(m)$ being consumption at time t by country (i,k) of good m from country (j,l).

The parameter ψ_i is a measure of trade integration for country i, ranging from 0 if it is perfectly integrated to 1 when it is in autarky. A couple of comments about this utility specification are in order. The friction we introduce to generate imperfect trade integration

little difference when we only consider heterogeneity in trade integration. But assuming wage stickiness simplifies the analysis when we also consider heterogeneous financial integration.

is home bias in preferences.[24] There are two types of home bias in preferences. First, country (i,k) has a bias towards its own goods and therefore a bias away from foreign goods. This is captured by the parameter ψ_i in the overall consumption index (3.3). In this case a larger ψ_i reduces imports. Second, to the extent that countries buy foreign goods, they have a different bias against goods from different countries. The index (3.4) implies that a larger ψ_j leads country (i,k) to have a larger bias against goods from country (j,l). Similarly, a larger ψ_i implies that all countries other than (i,k) have a larger bias against (i,k) goods, which reduces exports of country i. Putting the two together, a higher ψ_i simultaneously reduces imports and exports of (i,k). If we allowed a higher ψ_i only to reduce the imports by country (i,k), and not exports, a higher ψ_i would have a large effect on relative prices to generate balanced trade, which significantly complicates the analysis.

The budget constraint in period 1 is:

$$\int_0^1 P_1^{ik}(m)c_{ik,1}^{ik}(m)dm + \int\int\int_0^1 S_{ik,1}\frac{P_1^{jl}(m)}{S_{jl,1}}c_{jl,1}^{ik}(m)dmdjdl + B_{ik} + M_1^{ik} = \\ W_1^{ik}(1-u^{ik}) + \Pi_1^{ik} + \bar{M}_1^{ik} + S_{ik,1}T_1^{ik} \tag{3.6}$$

Here $P_1^{ik}(m)$ is the price of good m from country (i,k) measured in the currency of country (i,k), $S_{ik,1}$ is units of country (i,k) currency per unit of a base currency (denoted by b) and B_{ik} is holdings of a domestic bond. The latter is only domestically traded. M_1^{ik} are money holdings and $\bar{M}_1^{ik}$ is a money transfer at period 1 from the central bank. W_1^{ik} is the nominal wage rate, u^{ik} is the unemployment rate and Π_1^{ik} is profits from firms.[25] Thus, with a labor supply of 1, $W_1^{ik}(1-u^{ik})+\Pi_1^{ik}$ is nominal GDP of country (i,k) measured in its own currency. Finally T_1^{ik} is a net transfer from abroad measured in the base currency that will be discussed below.

The domestic bond of country (i,k) is in zero net supply and delivers R^{ik} units of country (i,k) currency in period 2. As we discuss further below, the absence of unexpected shocks in period 2 ensures that full employment is achieved in the last period. The period 2 budget

[24] An alternative would be to introduce trade costs, while leaving preferences the same for all countries. However, proportional trade costs have the disadvantage that no matter the level of these costs, as the relative size of countries goes to zero, the fraction of home goods countries consume approaches zero as well. One would need to introduce a fixed cost of goods trade to generate a positive fraction of home goods consumed for infinitesimally small countries, but this significantly complicates the analysis.

[25] In principle unemployment implies that some workers do not earn any labor income, but there may be a redistribution mechanism such that all households end up receiving $W_1^{ik}(1-u^{ik})$ regardless of their working status.

constraint is then

$$\int_0^1 P_2^{ik}(m)c_{ik,2}^{ik}(m)dm + \int\int\int_0^1 S_{ik,2}\frac{P_2^{jl}(m)}{S_{jl,2}}c_{jl,2}^{ik}(m)dmdjdl + M_2^{ik} = \tag{3.7}$$
$$W_2^{ik} + \Pi_2^{ik} + M_1^{ik} + R^{ik}B_{ik} + (\bar{M}_2^{ik} - \bar{M}_1^{ik}) + S_{ik,2}T_2^{ik}$$

We assume a cash-in-advance constraint with the buyer's currency being used for payment:

$$\int_0^1 P_t^{ik}(m)c_{ik,t}^{ik}(m)dm + \int\int\int_0^1 S_{ik,t}\frac{P_t^{jl}(m)}{S_{jl,t}}c_{jl,t}^{ik}(m)dmdjdl \leq M_t^{ik} \tag{3.8}$$

Let P_t^{ik} denote the country (i,k) consumer price index in the local currency and $P_t(i,k)$ the price index of country (i,k) goods measured in the country (i,k) currency. $P_{F,t}$ is the price index of all Foreign goods measured in the base currency. The first-order conditions are then[26]

$$\frac{1}{\left(c_1^{ik}\right)^{\lambda}} = \beta R^{ik}\frac{P_1^{ik}}{P_2^{ik}}\frac{1}{\left(c_2^{ik}\right)^{\lambda}} \tag{3.9}$$

$$c_{ik,t}^{ik} = \psi_i\frac{P_t^{ik}}{P_t(i,k)}c_t^{ik} \tag{3.10}$$

$$c_{F,t}^{ik} = (1-\psi_i)\frac{P_t^{ik}}{S_{ik,t}P_{F,t}}c_t^{ik} \tag{3.11}$$

$$c_{jl,t}^{ik} = \frac{1-\psi_j}{1-\bar{\psi}}\frac{S_{jl,t}P_{F,t}}{P_t(j,l)}c_{F,t}^{ik} \quad (i,k)\neq(j,l) \tag{3.12}$$

$$c_{jl,t}^{ik}(m) = \left(\frac{P_t(j,l)}{P_t^{jl}(m)}\right)^{\sigma}c_{jl,t}^{ik} \quad \forall(i,k),(j,l) \tag{3.13}$$

where the price indices are

$$P_t^{i,k} = P_t(i,k)^{\psi_i}(S_{i,k,t}P_{F,t})^{1-\psi_i} \tag{3.14}$$

$$P_t(i,k) = \left(\int_0^1 [P_t^{i,k}(m)]^{1-\sigma}djdl\right)^{\frac{1}{1-\sigma}} \tag{3.15}$$

$$ln\left(P_{F,t}\right) = \int\int_0^1 \frac{1-\psi_j}{1-\bar{\psi}}ln\left(\frac{P_t(j,l)}{S_{jl,t}}\right)djdl \tag{3.16}$$

[26]There is no expectation operation in the consumption Euler equation (3.9) as there are no unexpected period 2 shocks.

Countries are linked through both trade and financial integration. Financial integration occurs through risk-sharing, which leads to net transfers between countries. Country (i,k) receives a net transfer T_t^{ik} from abroad. We assume

$$T_t^{ik} = \int\int_0^1 E_t^W \phi_k \phi_l ln\left(\frac{g_1^{jl}}{g_1^{ik}}\right) djdl \tag{3.17}$$

Here E_t^W is nominal world exports in the base currency and g_1^{ik} is period 1 real output of country (i,k) relative to its expected value. The parameter ϕ_k is a measure of financial integration for country (i,k) and similarly ϕ_l for country (j,l). Under this specification, countries agree to pay to each other a fraction $\phi_k\phi_l ln\left(\frac{g_1^{jl}}{g_1^{ik}}\right)$ of nominal world exports. Country (i,k) receives a payment from country (j,l) when $g_1^{jl} > g_1^{ik}$ and makes a payment to (j,l) when $g_1^{jl} < g_1^{ik}$. Countries therefore make payments to each other based on their unexpected relative output performances. The size of these payments will be determined by their financial integration level, as well as by the integration level of the partners.[27] The transfers are scaled by world trade as transfers must necessarily vanish in the absence of trade. Transfers are only meaningful if countries can use them to buy goods from each other.

In Appendix C.4 we show that the expression for T_t^{ik} can be seen as the result of a particular asset market structure with a limited commitment financial friction. Also note that the transfers are assumed to be the same fraction of world exports in periods 1 and 2. They only depend on unexpected period 1 relative output. There will be two shocks in the model, country-specific productivity shocks and sunspot shocks. The country-specific productivity shocks occur in period 1 and are permanent (last two periods). For simplicity we assume that the sunspot shocks does not affect the risksharing scheme as it has infinitesimal probability from the perspective of period 0. Risk sharing is therefore based on the permanent productivity shocks.

3.3.2 Firms

In each country there is a continuum of firms of mass one. Each firm produces a different variety and sets its optimal price each period. Output of good m in period t of country (i,k)

[27]Also note that net payments are zero in aggregate because a positive payment to country (i,k) from country (j,l) implies a negative payment to country (j,l) by the exact same amount as measured by the base currency.

is

$$y_t^{ik}(m) = e^{x_{ik}} A_{ik,t}(m) L_t^{ik}(m) \tag{3.18}$$

where $L_t^{ik}(m)$ is labor input and $e^{x_{ik}} A_{ik,t}(m)$ is labor productivity. $A_{ik,t}(m)$ is an endogenous component of labor productivity that will be discussed below. The exogenous component x_{ik} is a country-specific i.i.d. shock with zero mean that is realized in period 1 and lasts both periods.

Since the production function is linear and all demands faced by the firm are CES with elasticity σ, the optimal price is a constant markup over marginal costs:

$$P_t^{ik}(m) = \frac{\sigma}{\sigma - 1} \frac{W_t^{ik}}{e^{x_{ik}} A_{ik,t}(m)} \tag{3.19}$$

In equilibrium all firms will set the same price, produce the same amount and hire the same number of workers, so that $P_t^{ik}(m) = P_t(i,k)$, $y_t^{ik}(m) = y_t^{ik}$ and $L_t^{ik}(m) = L_t^{ik}$. Thus profits can be written as

$$\Pi_t^{ik} = P_t(i,k) y_t^{ik} - W_t^{ik} L_t^{ik} = \frac{1}{\sigma} P_t(i,k) y_t^{ik} \tag{3.20}$$

That is, nominal profits are just a fraction $1/\sigma$ of nominal output. Dividing by the consumer price index, we obtain real profits:

$$\pi_t^{ik} = \frac{\Pi_t^{ik}}{P_t^{ik}} = \frac{1}{\sigma} \frac{P_t(i,k)}{P_t^{ik}} y_t^{ik} \tag{3.21}$$

Next consider the firm's intertemporal problem. In period 1 the productivity component $A_{ik,1}$ is assumed to be 1 for all countries and firms. In period 2 firms can maintain this productivity level if they pay a fixed cost κ, which is real (in terms of the consumption index). Otherwise this endogenous productivity component decreases to $A_L < 1$. The cost κ represents an investment required to maintain the productivity of the firm. This is a fixed cost. For example, a firm might shut down a department, branch, other facility or machine if it is unable or unwilling to bear the fixed costs associated with their operation. It might also shut down a worker training program, assuming again that this is a discrete choice. We assume that the cost κ is paid to intermediaries who bear no production costs and whose profits are simply returned to the households that own them. This simplifies in that the investment does not involve a real use of resources.

We assume that firms are borrowing constrained, so that they can only invest if they have sufficient internal funds. For simplicity, although this is not important, assume that firms cannot borrow at all and therefore need to finance the cost κ entirely from internal funds. The following borrowing constraint therefore holds if firms make the investment κ:

$$\pi_1^{ik} \geq \kappa \tag{3.22}$$

We will refer to this constraint as the borrowing condition. It is important to the mechanism of the model as it leads to a feedback from profits in period 1 to investment, which in turn affects productivity in period 2. We could relax the condition by assuming that firms can only borrow up to an amount of say z. In that case κ on the right hand side becomes $\kappa - z$. BvW show that if we relax the borrowing constraint enough, firms will always invest and we do not have self-fulfilling panics in the model. Tight credit is therefore an important vulnerability in the model, consistent with conditions during the Great Recession.

If firms can afford the real cost κ, they will invest as long as the present discounted value of profits when they invest is at least as high as when they do not invest. Using that the pricing kernel in this model is just β [28], this condition can summarized as

$$\Pi_1^{ik} + \beta \Pi_{2,I}^{ik}(m) - P_1^{ik}\kappa \geq \Pi_1^{ik} + \beta \Pi_{2,NI}^{ik}(m) \tag{3.23}$$

where $\Pi_{2,I}^{ik}(m)$ is second period profits if firm m invests and $\Pi_{2,NI}^{ik}(m)$ is second period profits if it does not invest. Rearranging this condition, we obtain

$$\frac{\beta \left(\Pi_{2,I}^{ik}(m) - \Pi_{2,NI}^{ik}(m)\right)}{P_1^{ik}} \geq \kappa \tag{3.24}$$

We will refer to this constraint as the incentive condition. It follows that $A_{ik,2}(m) = 1$ if and only if both the borrowing and the incentive condition are satisfied. Otherwise $A_{ik,2}(m) = A_L$.

3.3.3 Central Banks

We will be brief about central banks as they behave the same way as in BvW. They set the second period money supply to stabilize prices, so that $P_2^{ik} = P_1^{ik}$. They set the first period interest rate such that $R^{ik}\beta = 1$. This corresponds to the interest rate in the flexible price

[28] The follows from the households' intertemporal consumption Euler Equation in equilibrium.

version of the model. BvW also consider counter-cyclical monetary policy, but they show that this will not help to avoid a self-fulfilling panic when the central bank has little room to maneuver close to the ZLB. This is again a feature that was relevant during the Great Recession.

3.3.4 Market Clearing

The market clearing equations are

$$y_t^{i,k}(m) = c_{i,k,t}^{i,k}(m) + \int\int_0^1 c_{i,k,t}^{j,l}(m)djdl \quad \forall(i,k), m \tag{3.25}$$

$$\int_0^1 L_t^{i,k}(m)dm = L_{S,t}^{i,k} \quad \forall(i,k) \tag{3.26}$$

$$M_t^{i,k} = \bar{M}_t^{i,k} \quad \forall(i,k) \tag{3.27}$$

$$B_{i,k} = 0 \quad \forall(i,k) \tag{3.28}$$

where $L_{S,1}^{ik} = 1 - u^{ik}$ in period 1 and $L_{S,2}^{ik} = 1$ in period 2. Equation (3.26) says that in both periods the number of workers hired by firms must equal the measure of employed workers. We assume that the wage is set at the start of each period. The wage is set such that the labor market is expected to clear without unemployment.[29] In period 2 there are no unexpected shocks, so that there will be full employment. In period 1 an unexpected sunspot shock will reduce demand for labor, which leads to unemployment.[30]

3.3.5 Condensed Version of the Model

Using the budget constraints, first-order conditions, optimal price setting and market clearing equations, Appendix C.1 derives a condensed version of the model that solves consumption, output and real profits as a function of second period productivity in all countries. From hereon we will denote the endogenous component of second period productivity as A_{ik}, omitting the period 2 subscript. It turns out that consumption, output and real profits will

[29] See Taylor (1999) for a review of models using the expected market clearing mechanism.

[30] The permanent productivity shocks do not lead to unemployment. Higher permanent productivity leads to a higher real wage in both periods as a result of a lower price level. This follows from the price setting equation.

be the same in both periods, so we also omit time subscripts. Appendix C.1 shows that

$$
\begin{aligned}
c^{ik} &= G^{ik}\left(\frac{V_{ik}}{D_{ik}}\right)^{\psi_i}\bar{V}^{1-\psi_i} && (3.29)\\
y^{ik} &= V_{ik} && (3.30)\\
\pi^{ik} &= \frac{1}{\sigma}V_{ik}^{\psi_i}\left(D_{ik}\bar{V}\right)^{1-\psi_i} && (3.31)
\end{aligned}
$$

where

$$V_{ik} = e^{x_{ik}}A_{ik} \tag{3.32}$$

$$G_{ik} = 1 + \left(\frac{1-\bar{\psi}}{1-\psi_i}\right)\phi_k\left(Q - \bar{\phi} ln\ V_{ik}\right) \tag{3.33}$$

$$D_{ik} = 1 + \left(\frac{1-\bar{\psi}}{1-\psi_i}\right)\psi_i\phi_k\left(Q - \bar{\phi} ln\ V_{ik}\right) \tag{3.34}$$

$$Q = \int_0^1\int_0^1 \phi_l ln\ V_{jl} dj dl \tag{3.35}$$

$$ln\ \bar{V} = \int_0^1\int_0^1 \frac{1-\psi_j}{1-\bar{\psi}} ln\left(\frac{V_{jl}}{D_{jl}}\right) dj dl \tag{3.36}$$

and

$$\bar{\phi} = \int_0^1 \phi_l dl$$

This gives the solutions of c^{ik}, y^{ik} and π^{ik} as a function of second period productivity in all countries. This is not a complete solution to the model though as we have not yet solved for the endogenous productivity component A_{ik}. This in turn depends on whether the borrowing and incentive conditions are satisfied. If both are satisfied, $A_{ik} = 1$. Otherwise $A_{ik} = A_L$. We will refer to $A_{ik} = A_L$ as the panic state and $A_{ik} = 1$ as the non-panic state.

Appendix C.2 shows that the incentive condition can be expressed as

$$\frac{\beta\left(1 - A_L^{\sigma-1}\right)}{A_{ik}^{\sigma-1}}\pi^{ik} \geq \kappa \tag{3.37}$$

When a country does not panic ($A_{ik} = 1$), the term multiplying profits is lower than 1, so that the incentive condition is tighter than the borrowing condition. Under Assumption 3.38 below, when a country panics ($A_{ik} = A_L$) the term multiplying profits in the incentive condition is greater than 1, which implies that the borrowing constraint is more easily violated and is the binding condition.

Assumption 2.

$$A_L < \sigma\kappa < \beta\left(1 - A_L^{\sigma-1}\right), \quad and \ \sigma \geq 2 \tag{3.38}$$

Therefore (see also Appendix C.2) it follows that

$$\begin{aligned} A_{ik} &= A_L \text{ when } \pi^{ik} < \kappa & (3.39) \\ &= 1 \quad \text{when } \beta\left(1 - A_L^{\sigma-1}\right)\pi^{ik} \geq \kappa & (3.40) \end{aligned}$$

The panic condition in (3.39) is the violation of the borrowing condition when $A_{ik} = A_L$, which is the binding condition with a panic. The non-panic condition in (3.40) is the incentive condition when $A_{ik} = 1$, which is the binding condition without a panic.

A full solution of the model now involves a set of A_{ik} for all (i, k) that is consistent with (3.31)-(3.36) and (3.39)-(3.40). Any such set of A_{ik} describes an equilibrium to the model. In the next section we analyze such equilibria.

3.4 Analysis of Equilibria

Equilibria of the model depend on the assumed distribution across countries of the integration parameters ψ_i and ϕ_k. We first consider the case where all countries are equally integrated, so that $\psi_i = \psi$ and $\phi_k = \phi$ are equal across all countries. This allows us to generalize the two-country results from BvW to a multi-country setup with both partial trade and financial integration. After that we consider the implications of introducing integration heterogeneity across countries. We first discuss analytical results in two particular cases, one with heterogeneous trade integration but no financial integration and another with heterogeneous financial integration but homogeneous trade integration. After that we present numerical results for the case of both heterogeneous trade and financial integration, which connects most closely to the empirical evidence. These results are all derived in the absence of country-specific productivity shocks x_{ik}. At the end of the section we provide numerical results for the case where heterogeneous trade and financial integration is combined with country-specific productivity shocks.

3.4.1 Multiple Equilibria and Uniform Integration

Consider first the case of homogeneous integration: $\psi_i = \psi$ and $\phi_k = \phi$ for all (i,k) and $x_{ik} = 0$. It is easy to verify that under Assumption 3.38 there exists both an equilibrium where all countries panic and an equilibrium where none of the countries panic. To see this, when no country panics, we have $A_{ik} = 1$ for all (i,k). Then $Q = 0$, $D_{ik} = 1$ and $\bar{V} = 1$, so that (3.40) becomes $\beta\left(1 - A_L^{\sigma-1}\right) \geq \sigma\kappa$. This holds by Assumption 3.38. Similarly, when all countries panic we have $A_{ik} = A_L$ for all (i,k). This implies $Q = \bar{\phi} ln\ A_L$, $D_{ik} = 1$ and $\bar{V} = A_L$, so that (3.39) becomes $A_L < \sigma\kappa$. This again holds by Assumption 3.38.

The existence of both a symmetric panic and non-panic equilibrium can be understood as follows. If all households in the world expect a high level of income in period 2, first period consumption will be strong. Profits will then be high enough, so that all firms will invest and productivity and income will be high in period 2, consistent with expectations of high future income. If instead all households in the world expect much lower income in period 2, they reduce consumption in period 1. This reduces demand for goods, which reduces period 1 output and profits. Since profits are now insufficient to cover the investment cost, productivity and output will be lower in period 2, consistent with expectations of lower income in period 2. Beliefs about future income are therefore self-fulfilling.

Next consider whether there exist asymmetric equilibria, where a subset of countries panic ($A_{ik} = A_L$), while subset does not ($A_{ik} = 1$). In Appendix C.3 we prove the following proposition:

Proposition 6. *When $\psi_i = \psi$ and $\phi_k = \phi$ for all countries, there exists a continuous function $h(\psi, \phi)$, with $h > 0$ under perfect integration and $h < 0$ under autarky, such that*

1. *when $h(\psi, \phi) > 0$, there exist only equilibria where either all countries panic or all countries do not panic.*

2. *when $h(\psi, \phi) \leq 0$, there also exist equilibria where only a subset of countries panic*

3. *$h(\psi, \phi)$ is decreasing in ψ and increasing in ϕ.*

There is more integration when ψ is lower (trade integration) and ϕ is larger (financial integration). The third part of the proposition then says that the function $h(\psi, \phi)$ is higher the more integration. Under perfect integration $h > 0$, while under complete autarky $h < 0$.

The proposition then says that when countries are sufficiently integrated ($h(\psi, \phi) > 0$), asymmetric equilibria do not exist. Either all countries panic or none of the countries panic. If instead countries are insufficiently integrated ($h(\psi, \phi) \leq 0$), asymmetric equilibria do exists where some countries panic and others do not.

Several points should be made about this result. First, only partial integration is sufficient to ensure that equilibria are coordinated across countries, where either all countries panic or none do. The function $h(\psi, \phi)$ will be positive under less than full integration.[31] Second, the two sources of economic integration are substitutes: with more financial integration, less trade integration is required to ensure that $h(\psi, \phi)$ is positive, so that a panic is necessarily global by part 1 of the proposition.

The proposition generalizes the results of BvW to a multi-country setup with both trade and financial integration. To understand these results, it is important to point out that there are positive linkages in the model through both trade and financial integration. A higher level of income in one region of the world leads to a higher demand for goods from the rest of the world (trade integration), while it also leads to higher net transfers to the rest of the world (financial integration). These positive linkages create an interdependence that leads to the coordination of panics when countries are sufficiently integrated.

Consider for example the case where a large subset of countries panics, while a smaller subset does not panic. When the level of integration is relatively high, this cannot be an equilibrium. The smaller subset is very negatively impacted by the panic in most of the world. This will reduce their income and profits through both trade and financial linkages, so that (3.40) does not hold and they must necessarily panic as well. Similarly, it is not possible for only a small subset of countries to panic under sufficient integration. They will be positively affected by the absence of a panic in most of the world. Their profits will then be high, so that they can cover the investment cost, (3.39) does not hold and they cannot panic in equilibrium. Sufficient integration assures that countries share a common fate.[32]

[31] Note that $h(\psi, \phi)$ is positive under perfect integration. Together with the fact that it is a continuous function that is decreasing in ψ and increasing in ϕ, it follows that the cutoff $h(\psi, \phi) = 0$ occurs under partial integration.

[32] The same intuition applies as well when half the countries panic and half do not. This brings us essentially in the BvW framework of a two-country model.

3.4.2 Integration Heterogeneity

We can provide theoretical results for two intermediate cases of integration heterogeneity. The first is one of heterogeneous trade integration, but no financial integration, where $\psi_i = 1-i$ and $\phi_k = 0$. The second is one with heterogeneous financial integration and homogenous trade integration, where $\phi_k = k$ and $\psi_i = \psi$. In the latter case, trade integration cannot be too low as financial integration is meaningless without the ability to trade goods. At the same time, trade integration cannot be too high as it would obviate the need for financial integration by generating endogenous risksharing through the terms of trade familiar from Cole and Obstfeld (1991). After discussing these two cases, we consider numerically the case of both trade and financial integration heterogeneity.

Trade Integration Heterogeneity

First consider the case where countries are in financial autarky and trade integration varies uniformly across countries from 0 (perfect integration) to 1 (autarky), with $\psi_i = 1 - i$. It follows that $\bar{\phi} = 0$, $Q = 0$ and $D_{ik} = 1$. Conditions (3.39)-(3.40) and (3.36) then become

$$\begin{aligned} A_{ik} &= A_L \ \text{ when } \ A_L^{\psi_i} \bar{V}^{1-\psi_i} < \sigma\kappa && (3.41) \\ &= 1 \quad \text{when } \ \beta \left(1 - A_L^{\sigma-1}\right) \bar{V}^{1-\psi_i} \geq \sigma\kappa && (3.42) \end{aligned}$$

$$ln\ \bar{V} = \int \int_0^1 \frac{1-\psi_j}{1-\bar{\psi}} ln\ A_{jl} dj dl \qquad (3.43)$$

Define $\tilde{\psi}_1(\bar{V})$ as the value of ψ_i for which the panic condition (3.41) holds with equality and $\tilde{\psi}_2(\bar{V})$ as the value of ψ_i for which the non-panic condition (3.42) holds with equality. Appendix C.3 defines $\bar{\sigma}$, $\bar{V}_1$ and $\bar{V}_2$ as a function of model parameters, with $A_L < \bar{V}_2 < \bar{V}_1 < 1$. It then provides a proof for the following Proposition:

Proposition 7. *Assume that $\psi_i = 1-i$, $\phi_k = 0$, and $\sigma > \bar{\sigma}$. Then there exists a continuum of equilibria of two types:*

1. *There is an interval $[\bar{V}_1, 1]$ such that for each $\bar{V}$ in the interval there are equilibria with two features. First, none of the countries in the interval $\psi_i \in [0, \tilde{\psi}_1(\bar{V})]$ panic. Second, when $\bar{V} < 1$ at least some of the remaining countries will panic.*

2. *There is an interval* $\left[A_L, \bar{V}_2\right]$ *or* $\left[A_L, \bar{V}_2\right\rangle$ *such that for each* $\bar{V}$ *in the interval there are equilibria with two features. First, all countries in the interval* $\psi_i \in [0, \tilde{\psi}_2(\bar{V})]$ *panic. Second, when* $\bar{V} > A_L$ *at most a subset of remaining countries will panic.*

There is a continuum of equilibria characterized by different values for $\bar{V}$ and, for a given $\bar{V}$, by different sets of countries that panic that is consistent with that $\bar{V}$. The first part of the proposition is relevant for large values of $\bar{V}$. In all of these equilibria none of the most integrated set of countries ($\psi_i \leq \tilde{\psi}_1(\bar{V})$) will panic, while in general a subset of the less integrated countries does panic. From the point of view of the Great Recession, the second type of equilibria in Proposition 2 is of most interest. It is relevant for low values of $\bar{V}$. In all of these equilibria all of the most integrated countries ($\psi_i \leq \tilde{\psi}_2(\bar{V})$) will panic together, while at most a subset of the less integrated countries panic. In the second set of equilibria there is a minimum set of integrated countries that panics, defined as $\psi_i \in [0, \tilde{\psi}_2(\bar{V}_2)]$. When this minimum set of integrated countries panics, none of the less integrated countries will panic.

The most integrated countries either panic together as a group or do not panic as a group, while the less integrated countries generally do not share their fate. The intuition for this is exactly the same as for Proposition 6. The interdependence of the integrated countries through trade and financial linkages implies a coordination of equilibria among the most integrated countries. The less integrated countries generally do not share this fate as they are less affected by what is happening in the rest of the world.

Financial Integration Heterogeneity

The second case that is analytically tractable allows for financial integration heterogeneity ($\phi_k = k$) while keeping constant the level of trade integration for all countries ($\psi_i = \psi$). As already discussed, in this case the level of trade integration cannot be too low or too high. We assume that $\psi \in (\psi_{low}, \psi_{high})$, where ψ_{low} and ψ_{high} are defined in the Technical Appendix C.3 as a function of model parameters. Rather than consider all possible equilibria, we will focus here on the ones most relevant in the context of the Great Recession, where the most integrated countries panic. This is analogous to the second part of Proposition 2 for the case of trade heterogeneity.[33] In Appendix C.3, we are able to prove the following Proposition:

[33] One can show that equilibria analogous to the first part of Proposition 7 still exist as well.

Proposition 8. *Assume that $\phi_k = k$ and $\psi_i = \psi$. For each $\psi \in (\psi_{low}, \psi_{high})$, the following equilibria exist:*

1. *There is an equilibrium where $\left(\bar{V}, Q\right) = \left(\bar{V}^*, Q^*\right)$, such that all countries on the interval $\left\langle \tilde{\phi}, 1\right]$ panic and none of the countries in the interval $\left[0, \tilde{\phi}\right]$ panic.*

2. *In addition, there are equilibria where $\left(\bar{V}, Q\right) < \left(\bar{V}^*, Q^*\right)$, such that all countries on the interval $\left[\tilde{\phi}\left(\bar{V}, Q\right), 1\right]$ panic, with $\tilde{\phi} < \tilde{\phi}^*$. When $\left(\bar{V}, Q\right) > \left(A_L, \bar{\phi} \ln A_L\right)$, a subset of the remaining countries also panics.*

The message from this proposition is analogous to what we found for the second type of equilibria in Proposition 2, as we now have that countries that are sufficiently financially integrated must panic together as a group. There is a minimum set of integrated countries that panics in these equilibria, defined as $\phi_k \in [\tilde{\phi}^*, 1]$. When this minimum set of integrated countries panics, none of the less integrated countries will panic.

Trade and Financial Integration Heterogeneity

We now consider the general case with both trade and financial integration heterogeneity. This case is too complex for a general analytical solution and we proceed numerically. Using the equilibrium expression for profits, we can write (3.39)-(3.40) as

$$\begin{aligned} A_{ik} &= A_L \text{ when } A_L^{\psi_i}\left[1+\left(\frac{1-\bar{\psi}}{1-\psi_i}\right)\psi_i\phi_k\left(Q-\bar{\phi}\ln\ A_L\right)\right]^{1-\psi_i}\bar{V}^{1-\psi_i} < \sigma\kappa \quad (3.44) \\ &= 1 \quad \text{when } \beta\left(1-A_L^{\sigma-1}\right)\left[1+\left(\frac{1-\bar{\psi}}{1-\psi_i}\right)\psi_i\phi_k Q\right]^{1-\psi_i}\bar{V}^{1-\psi_i} \geq \sigma\kappa \quad (3.45) \end{aligned}$$

In the cases discussed above that we could solve analytically, we saw that there is a minimum set of integrated countries that panics. If only this minimum set of integrated countries panics, none of the less integrated countries panic. We can associate this equilibrium with a pair $(Q^*, \bar{V}^*)$. We will focus on this equilibrium in the numerical solution. In general, as we have seen, there will also be equilibria where a larger group of integrated countries panics and a subset of the less integrated countries panics as well.

We briefly describe the numerical solution method. We start with a given pair $(Q_0, \bar{V}_0)$ large enough so that $(Q_0, \bar{V}_0) > (Q^*, \bar{V}^*)$ but low enough so that (3.44) holds even for the most integrated countries. For each country we then evaluate (3.45). If this condition does not hold, only the panic equilibrium is feasible for this country and we correspondingly assign $A_{ik} = A_L$. If (3.45) holds, we assume that the country does not panic, so $A_{ik} = 1$, as we are seeking the minimum set of countries that must panic. These solutions for A_{ik} imply new values Q_1 and $\bar{V}_1$ such that either $Q_1 < Q_0$ or $\bar{V}_1 < \bar{V}_0$ or both hold.[34] It follows that the original pair $(Q_0, \bar{V}_0)$ cannot be an equilibrium, because setting $A_{ik} = A_L$ for any set of countries that also satisfy (3.45) only decreases Q_1 and $\bar{V}_1$ even further. We then proceed as before by picking the new pair $(Q_1, \bar{V}_1)$, solving the A_{ik} and continue to iterate along this line until Q and $\bar{V}$ converge to the equilibrium pair $(Q^*, \bar{V}^*)$. Thus the numerical method allows us to establish that there are only equilibria such that $(Q, \bar{V}) \leq (Q^*, \bar{V}^*)$, and at the same time it provides an iterative procedure to find the equilibrium.[35]

The process of numerical convergence is closely connected to the economic intuition behind these equilibria. When a sufficiently large set of countries panics, the interdependence of the integrated countries through trade and financial linkages implies that even more countries must panic. In turn this increased set of countries triggers a panic in some of the less integrated countries. This process continues until the remaining countries are sufficiently disconnected from the rest of the world that they can avoid a panic even if most of the world panics.

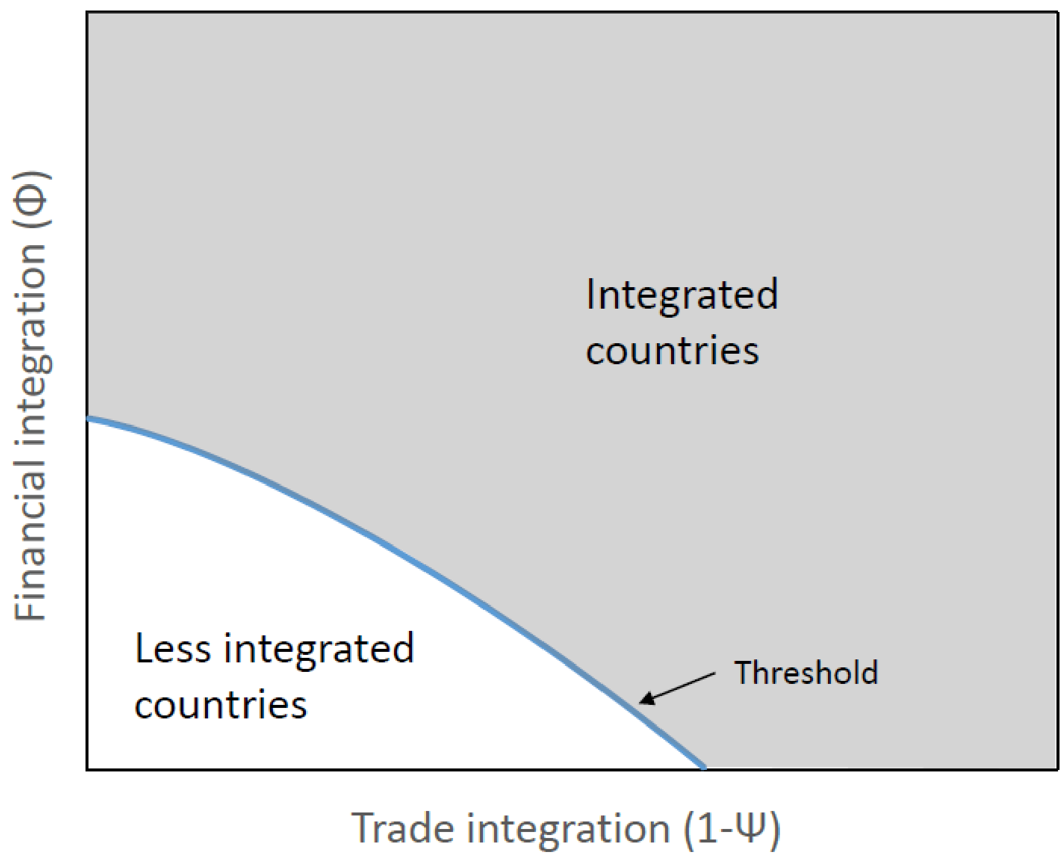
Figure 16 provides an illustration. We assume that countries are distributed such that $\psi_i = (1 - \theta_T)(1 - \alpha_T i)$ and $\phi_k = \theta_F + \alpha_F k$, where $\theta_T = 0.07$, $\alpha_T = 0.34$, $\theta_F = 0$ and $\alpha_F = 1.83$. These values are chosen such that the most integrated country enjoys full risk-sharing in normal times (when $A_{ik} = 1$ for all countries), while at the same time there are no countries in complete autarky.[36] The remaining parameter values $\sigma = 28.95$, $\kappa = 0.03$, $\beta = 1$ and $A_L = 0.9$ are chosen such that Assumption 3.38 holds, monetary policy is constrained at the ZLB, and output drops by 10% during a panic.

[34]We compute these values of Q and $\bar{V}$ using the concept of the Riemann sum as an approximation to the Riemann integral. We first set a grid of 200^2 points in the unit square to approximate a continuum of countries, and then we approximate the integrals (3.35)-(3.36) computing the corresponding Riemann sums for all small increments in the two-dimensional grid. We test the accuracy of this method by calculating the equilibrium value of $\bar{V}_2$ in the context of Proposition 7, which can also be computed with a standard numerical solver as the solution of a non-linear equation. Due to the density of the two-dimensional grid we employ, we find that both methods provide the exact same solution.

[35]Given that the left-hand-side of (3.45) is decreasing in Q and $\bar{V}$, other possible equilibrium pairs necessarily involve a larger set of countries that panic than the set associated with $(Q^*, \bar{V}^*)$.

[36]The values also ensure that (3.39)-(3.40) cannot hold simultaneously for very integrated countries. This way we ensure the existence of the same type of equilibria as in the second part of Proposition 2.

Figure 16: Countries in the tradefinancial space



The figure is in the space of trade and financial integration. On the horizontal axis we have $1 - \psi_i$, a measure of trade integration. On the vertical axis we have ϕ_k, a measure of financial integration. These correspond well to the counterparts of trade and financial integration in the empirics. In Appendix C.1 we show that total exports by country (i, k) are proportional to $(1 - \psi_i)$. Similarly, we show in Appendix C.4 that ϕ_k can be seen as the theoretical counterpart of the measure of financial integration from the empirics.

In the equilibrium that we analyze all the integrated countries panic, while all the less integrated countries do not panic. All the integrated countries are above the threshold line shown in Figure 16, while all the less integrated countries are below the threshold line. This corresponds well to the empirical results for the Great Recession. First, it is consistent with the result that the drop in output was larger during the Great Recession for countries whose integration level was beyond some threshold than for countries that were less integrated.[37] Second and related, it is consistent with evidence that there is no monotonic relationship between integration and the drop in output. Within each group of countries the level of output is identical. Integration only matters in terms of what side of the threshold countries are. Third, trade and financial integration are substitutes. As a country's trade integration increases, a lower level of financial integration is needed to reach the threshold line. It follows that it is a combination of the two types of economic integration that matters in classifying countries as integrated or less integrated.

Finally, it is worth noting the crucial role that financial integration plays in this example. If all countries were in financial autarky ($\phi_k = 0$), with the remaining parameter values the same, there do not exist coordinated equilibria as the level of trade integration is too low. It is the extent of heterogenous financial integration across countries that makes the difference here, by strengthening the positive linkages within the integrated group.

3.4.3 Allowing for Random Shocks

We finally consider the most general possible case, with both trade and financial integration heterogeneity and country-specific productivity shocks x_{ik} that last both periods. From a mathematical perspective, little changes relative to the previous subsection. Using the Law of Large Numbers, we can replace each random term inside the integrals (3.35)-(3.36) by

[37] Output equals respectively A_L and 1 for integrated and less integrated countries.

its expectation.[38] The aggregate solution of the model will therefore not depend on which particular countries are hit by good or bad shocks, or the magnitude of these shocks. In terms of $(Q, \bar{V})$ space, the equilibria are therefore the same as before: $(Q, \bar{V}) \leq (Q^*, \bar{V}^*)$, with the latter solved with the same iteration procedure as before.

Once we have the pair $(Q^*, \bar{V}^*)$, we can evaluate the non-panic condition (3.40), which now depends on ψ_i, ϕ_k and x_{ik}, to decide which countries necessarily panic. What changes now is that relatively integrated countries can avoid a panic if they get hit by a big enough positive shock x_{ik} because good domestic conditions keep profits strong so that lucky countries can invest and avoid a panic. Similarly some relatively less integrated countries hit by a negative shock can fall in a panic because bad domestic conditions exacerbate the impact of poor foreign conditions.

An intuitive way to illustrate the role of trade and financial integration is in terms of probabilities of experiencing a panic. Conditional on the pair $(Q^*, \bar{V}^*)$, these probabilities are given by

$$\Pr(\pi^{ik}(\psi_i, \phi_k, x_{ik}, Q^*, \bar{V}^*) < \kappa/[\beta\left(1 - A_L^{\sigma-1}\right))] \tag{3.46}$$

This is the probability that (3.40) does not hold, so that the country must panic. A panic then occurs when $x_{ik} < x(\psi_i, \phi_k)$, where $x(\psi_i, \phi_k)$ is the value of x_{ik} such that $\pi^{ik} = \kappa/[\beta\left(1 - A_L^{\sigma-1}\right)]$ as an equality. Solving for $x(\psi_i, \phi_k)$ then easily lets us compute the panic probability for a given distribution of the x_{ik}.

Figure 17 provides an illustration. The equilibrium $(Q^*, \bar{V}^*)$ is computed for the same parameter values as in the previous subsection and we plot the continuum of countries in the unit square.[39] We assume $x_{ik} \sim N(0, 0.005)$ for all countries. The figure plots the probability contour map associated with the equilibrium pair $(Q^*, \bar{V}^*)$.

It is clear from this picture that it is no longer the case that necessarily all integrated countries panic as a group. The probabilities of a panic are much higher for integrated countries, but it is now possible that an integrated country does not panic if it gets a very positive productivity shock. Similarly, less integrated countries may be hit by a very bad shock and together with the negative spillovers from the global panic could fall into a panic. This leads to differences across countries in growth that are unrelated to levels of integration. It remains the case that there is a strong threshold, but consistent with

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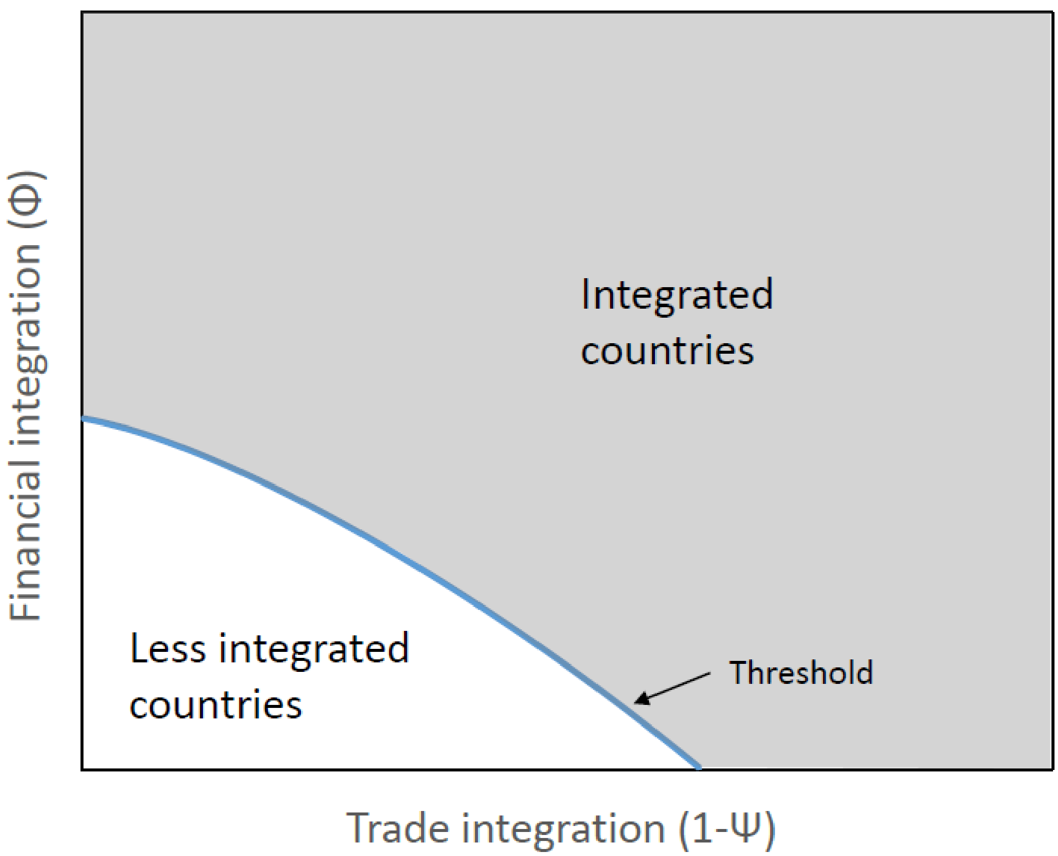
[38] See Uhlig (1996).

[39] Since the expressions for ψ and ϕ are linear in i and k, the unit square can also be interpreted as the trade/financial space.

Figure 17: Probability Contour Map



the data there are now some less integrated countries that perform very poorly and some integrated countries that perform well. This is consistent with Figure 15, where we saw that not all integrated countries are bad performers and not all less integrated countries are good performers. Integration matters in a threshold type of way, but pure country-specific randomness certainly plays a role as well.

3.5 Conclusion

In the introduction we argued that two features characterize cross-country business cycle synchronicity during the Great Recession. The first is that the degree of business cycle synchronicity at this time was historically unparalleled. The second feature is about the relationship between economic integration and the extent that countries were impacted by the Great Recession. While there is no robust monotonic relationship between levels of integration and the drop in output during the Great Recession, we have developed evidence of a strong non-linear relationship. Countries below a certain threshold of integration, capturing both trade and financial integration, were much less affected than those above the threshold.

We have shown that these features are consistent with a model that extends the two-country BvW model of self-fulfilling business cycles to a multi-country setting with heterogeneity across countries with regard to both trade and financial integration. We find that integrated countries necessarily panic as a group as their interconnectedness makes it impossible to have widely varying outlooks on the future. At the same time less integrated countries are less dependent on other countries and therefore in equilibrium may not panic even if most of the rest of the world panics. This creates a dichotomy, with a larger drop in output for countries whose level of integration is above a certain threshold cutoff than those that are less integrated. Within both groups of countries the theory implies no relationship between the decline in output and the level of integration. This explains why integration only matters in a discontinuous way.

Appendix A

Appendix for Chapter 1

A.1 Data

A.1.1 Quarterly Finance Report

The Quarterly Finance Report (QFR) includes all corporations engaged primarily in manufacturing with total assets of $250,000 and over, and all corporations engaged primarily in mining, wholesale trade, and retail trade industries with total assets of $50 million and over. The QFR sampling frame is developed from a file received annually from the IRS. Another random samples are selected for firms have less than $250,000 total assets. Each firm in the random sample is kept for eight successive quarters. The QFR separately reports representative income statement and balance sheet for big corporations, small business and industry total for 31 industries.

In our analysis, the industry total is used. All sales value in the QFR is in nominal term. I deflate all series by the U.S. GDP deflator with the 2009 dollar equal to 100 and adjust for seasonality using the X–12–ARIMA seasonal adjustment program. Last, we combine the sales from the QFR with gross output value provided by the Bureau of Economic Analysis (BEA). The sample consists of 44 non-FIRE private sectors. Table 28 reports the list of sectors and their main characteristics. 'Consumption' and 'input' are respectively the shares of products used as consumption goods and intermediate inputs. $\Delta\frac{AR}{S}$ and $\Delta\frac{AP}{OC}$ are defined in Section 1.2.4. BL_Shock is defined in Section 1.2.4.

A.1.2 Compustat

Following Kahle and Stulz (2013), we use Compustat Database and create our firm-level sample by filtering out

- Observations with negative totala ssets (atq), negative sales (saleq), negative cash and marketable securities,cash and marketable securities greater than total assets;
- Firms not incorporated in the US;
- All financial firms (firms with standard industrial classification(SIC) codes between 6000 and and 6999);
- Firms with market capitalization less than \$50 million and with book value of assets is less than \$10 million
- Firms with quarterly asset or sales growth greater than 100% at some point during sample period
- Observations which have cash and marketable securities greater than total assets;

Then we construct measurements for the intensity of trade credit provision and reception as

$$Intensity\ of\ Trade\ Credit\ Provision = \frac{Accounts\ Receivables\ (rectq)}{Total\ Sales\ (sales)};$$

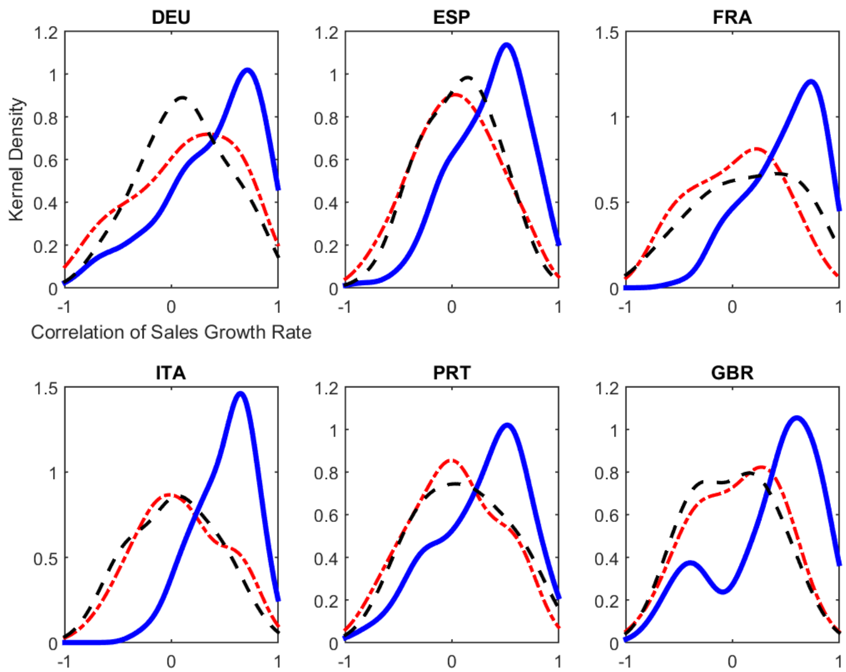
$$Intensity\ of\ Trade\ Credit\ Reception = \frac{Accounts\ Payables(apq)}{Operational\ Costs\ (cogsq) + \Delta Inventory\ (invtq)};$$

A.2 Sectoral Comovemeng in European Countries

EuroStat Database provides the information about production in industries for major European countries. I choose the same period as in Section 1.2.2 and calculate the pairwise correlations among sectors. Figure 18 displays the kernel densities of the pairwise correlations in Germany, Spain, France, Italy, Portugal, and UK. As in the U.S., these European countries have experience the similar increase in sectoral comovement.

Using the same dataset, we also examine the sectoral comovement during the European Debt Crisis. Figure 19 shows the kernel densities of the pairwise correlations for Spain, Italy, Greece and Germany with the crisis period starting at 2011Q3. I find the increase in sectoral comovement in Spain, Italy and Greece, but not in Germany, France and the UK.

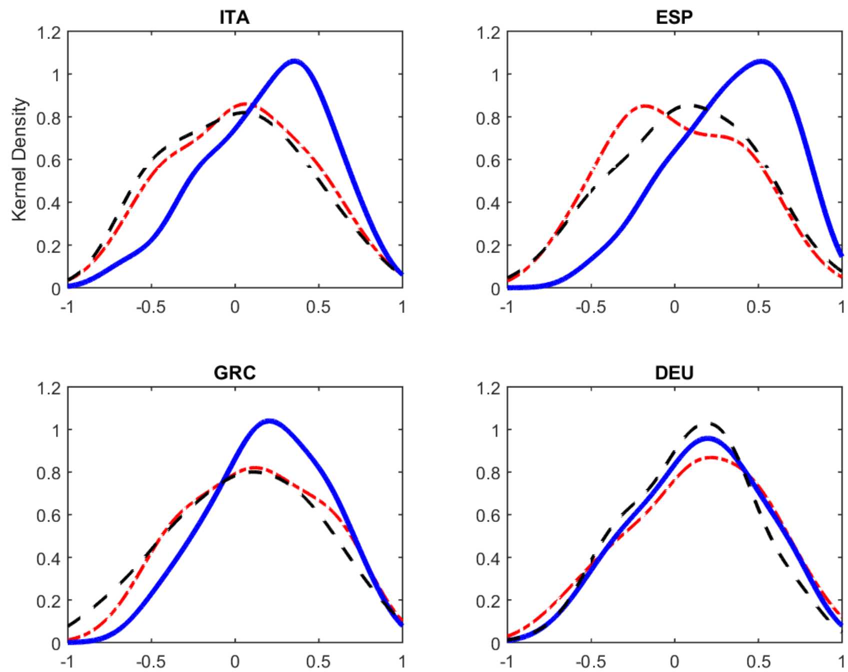
Figure 18: Pairwise Correlations of Major European Countries during the Great Recession



A.3 Robustness Check for Other Decompositions

Mian and Sufi (2010) and Mian et al. (2013) document that the U.S. experienced a large decline across various types of consumption goods during the Great Recession. It indicates that sectors providing more of their products as consumption goods would be more likely to move together driven by such decline in consumption. To test this, we divide all sectors into two groups based on the share of their products used mainly as consumption goods or intermediate inputs in 2007. One sector is categorized in the consumption–goods group if the share of products used as consumption goods is more than the median value, namely 30%, across sectors. On the other hand, it is classified in the intermediate–inputs if the sector provide more than 60% of their goods as intermediate inputs, where 60% is the median value of such shares across sectors. Figure 20 shows the comparison for the kernel densities during the Great Recession across two groups, where the blue solid and red dashed lines represent

Figure 19: Pairwise Correlations of Major European Countries during the European Debt Crisis



the final goods and intermediate inputs group respectively. The figure suggests the opposite to our expectation. In particular, the intermediate–inputs group has higher correlation, by 0.17 on average and 0.23 on median. The KS statistics for comparing the densities across groups is 0.12, which is more than the critical value at the 0.1% significance level. It means that two kernel densities are statistically significantly different from each other. Moreover, in the online Appendix, we show that the kernel densities before (after) the recession for two groups are not statistically significantly different from each other. This finding confirms the stylized fact II in Sector 1.2.3 and demonstrate the relevance of input-output linkage among sectors with the rise in sectoral comovement.

A.4 Regression about the Importance of Trade Credit

In this section, we study the relevance of the change in trade credit with the rise in sectoral comovement through a linear regression as

$$\Delta \mathbf{corr}_{ij} = \alpha_0 + \alpha_1 \mathbf{D}^{tc} + \alpha_2 \mathbf{D}^{tf} + \alpha_3 \mathbf{D}^{bl} + \alpha_4 \mathbf{D}^{tc} \times \mathbf{D}^{tf} + \alpha_5 \mathbf{D}^{tc} \times \mathbf{D}^{bl} + \beta_1' \Delta X_i + \beta_2' \Delta X_j \epsilon_{ij} \quad \text{(A.1)}$$

where $\mathbf{D}^{tc}$, $\mathbf{D}^{tf}$, and $\mathbf{D}^{bl}$ are respectively defined in Equation 1.2, 1.5, and 1.6, and X contains sectoral characteristics such as the share of intermediate inputs share over the total output value, extensive margin of sectoral connectedness, intensive margin of sectoral connectedness, and output share for final usage. Both OLS and Tobit regression are applied. Table 30 shows the results. The coefficient of trade credit group is statistically significant and the results are robust even after controlling sectoral characteristics.

A.5 Comparison: Kernel Densities before (after) the Great Recession

Figure 21 and 22 respectively display the kernel densities of three types of interconnectedness before and after the Great Recession. Figure 23 and 24 show that the kernel densities of two trade-credit groups before and after the Great Recession.

A.6 Proof of Lemmas and Propositions

A.6.1 Proof of Lemma 1

Suppose μ_i is the Lagrange multiplier for the financial constraint of firms in sector i. Then the Lagrangian for firms' problem is

$$\begin{aligned} \mathcal{L} \;=\; & p_i z_i \prod_{j=1}^{N} m_{ji}^{\omega_{ji}} l_i^{\alpha_i} - \sum_{j=1}^{N} \kappa d_{ij} p_i m_{ij} - w l_i - \sum_{j=1}^{N} (1-\kappa d_{ji}) p_j m_{ji} - \varphi_i \sum_{j=1}^{N} \left(d_{ij} - \bar{d}_i\right)^2 p_i m_{ij} \\ & + \mu_i \Big(e_i p_i c_i + \sum_{j=1}^{N} (1-d_{ij}) p_i m_{ij} - w l_i + \sum_{j=1}^{N} (1-d_{ji}) p_j m_{ji} \Big) \qquad \text{(A.2)} \end{aligned}$$

The first order conditions for l_i and m_{ji} are

$$(l_i) \qquad \alpha_i \frac{p_i y_i}{l_i} = (1+\mu_i) w \tag{A.3}$$

$$(m_{ji}) \qquad \omega_{ji} \frac{p_i y_i}{m_{ji}} = (1 - \kappa d_{ji} + (1-d_{ji})\mu_i) p_j \tag{A.4}$$

Let

$$\theta_i^l = \frac{1}{1+\mu_i} \tag{A.5}$$

$$\theta_{ji}^m = \frac{1}{1 - \kappa d_{ji} + (1-d_{ji})\mu_i} \tag{A.6}$$

Then, combining Equation (A.5) with (A.3), I have Equation (1.12); and combining Equation (A.6) with (A.4), I have Equation (1.13).

A.6.2 Proof of Lemma 2

The Lagrangian for firms' problem in the second step is

$$\begin{aligned} \mathcal{L}^d &= \left(1 - \kappa d_{ij} - \varphi_i \left(d_{ij} - \bar{d}_i\right)^2 + (1-d_{ij})\,\mu_i\right) \omega_{ij} \theta_{ij}^m p_j y_j \\ &\approx \frac{1 - \kappa d_{ij} - \varphi_i \left(d_{ij} - \bar{d}_i\right)^2 + (1-d_{ij})\mu_i}{1 - \kappa d_{ij} + (1-d_{ij})\mu_j} \end{aligned}$$

The first order conditions for d_{ij} is

$$\varphi_i (\kappa + \mu_j) \left(d_{ij} - \bar{d}_i\right)^2 - 2\varphi_i \left(1 + \mu_j - (\kappa+\mu_j)\,\bar{d}_i\right)\left(d_{ij} - \bar{d}_i\right) = (1-\kappa)\,(\mu_i - \mu_j) \tag{A.7}$$

Solving Equation (A.7) for d_{ij}, we have Equation 1.14.

A.6.3 Proof of Proposition 1

Rewriting Equation A.7, we have

$$-\varphi_i \left(d_{ij} - \bar{d}_i\right) \left(2\,(1+\mu_j) - (\kappa+\mu_j) d_{ij} - (\kappa+\mu_j)\,\bar{d}_i\right) = (1-\kappa)\,(\mu_i - \mu_j) \tag{A.8}$$

Since $d_{ij} \leq 1$, $\bar{d}_i \leq 1$, and $\kappa < 1$, then $2(1+\mu_j) - (\kappa+\mu_j)d_{ij} - (\kappa+\mu_j)\bar{d}_i > 0$. If $\mu_i = \mu_j$, then the LHS of Equation (A.7) is equal to zero. This implies $d_{ij} = \bar{d}_i$. If $\mu_i > \mu_j$, then the LHS of Equation (A.7) is positive, which further implies $d_{ij} < \bar{d}_i$. If $\mu_i < \mu_j$, then the LHS of Equation (A.7) is negative, which further implies $d_{ij} > \bar{d}_i$.

Taking the first derivative of Equation (1.14), I have

$$\frac{\partial d_{ij}}{\partial \mu_i} = -\frac{1-\kappa}{2\varphi_i\left(1-\kappa d_{ij}+\left(1-d_{ij}\right)\mu_j\right)} < 0 \tag{A.9}$$

$$\frac{\partial d_{ij}}{\partial \mu_j} = \frac{1-\kappa-\varphi_i\left(d_{ij}-\bar{d}_i\right)\left(2-d_{ij}-\bar{d}_i\right)}{2\varphi_i\left(1-\kappa d_{ij}+\left(1-d_{ij}\right)\mu_j\right)} \tag{A.10}$$

Since $\left(d_{ij}-\bar{d}_i\right)\left(2-d_{ij}-\bar{d}_i\right) = -\left(1-d_{ij}\right)^2 + \left(1-\bar{d}_i\right)^2 < \left(1-\bar{d}_i\right)^2$, then

$$\frac{\partial d_{ij}}{\partial \mu_j} > \frac{1-\kappa-\varphi_i\left(1-\bar{d}_i\right)^2}{2\varphi_i\left(1-\kappa d_{ij}+\left(1-d_{ij}\right)\mu_j\right)} > 0 \tag{A.11}$$

A.6.4 Proof of Proposition 2

It is trivial to show that $\frac{\partial \theta_i^l}{\partial \mu_i} < 0$. Then, combining Equation (A.6) with (1.14), I have

$$\theta_{ji}^m = \sqrt{\frac{1}{\left(1-\kappa\bar{d}_j+\left(1-\bar{d}_j\right)\mu_i\right)^2 + \frac{1-\kappa}{\varphi_j}\left(\mu_j-\mu_i\right)\left(\kappa+\mu_i\right)}}$$

It is trivial to show that $\frac{\partial \theta_{ji}^m}{\partial \mu_j} < 0$. Let

$$\begin{aligned} g &= \left(1-\kappa\bar{d}_j+\left(1-\bar{d}_j\right)\mu_i\right)^2 + \frac{1-\kappa}{\varphi_j}\left(\mu_j-\mu_i\right)\left(\kappa+\mu_i\right) \\ &\approx -\frac{1-\kappa-\varphi_j\left(1-\bar{d}_j\right)^2}{\varphi_j}\mu_i^2 + \left(2\left(1-\kappa\bar{d}_j\right)\left(1-\bar{d}_j\right) + \frac{1-\kappa}{\varphi_i}\left(\mu_j-\kappa\right)\right)\mu_i \end{aligned}$$

Then I have $\frac{\partial g}{\partial \mu_i} > 0$ for $\mu_i < \frac{2\varphi_j\left(1-\kappa\bar{d}_j\right)\left(1-\bar{d}_j\right)+(1-\kappa)(\mu_j-\kappa)}{1-\kappa-\varphi_j\left(1-\bar{d}_j\right)^2}$ and $\frac{\partial g}{\partial \mu_i} \leq 0$, otherwise. The former implies $\frac{\partial \theta_{ji}^m}{\partial \mu_i} < 0$, whereas the latter suggests $\frac{\partial \theta_{ji}^m}{\partial \mu_i} \geq 0$. Moreover, the assumption, $\kappa < 2\varphi_i\left(1-\bar{d}_i\right)$, implies that $2\varphi_j\left(1-\kappa\bar{d}_j\right)\left(1-\bar{d}_j\right) + (1-\kappa)(\mu_j-\kappa) > 0$.

A.6.5 Proof of Proposition 3

First, I want to show that there exists $\bar{\xi}_i^l$ such that for all $xi_i^l < \bar{\xi}_i^l$,

$$\xi_i^l p_i y_i - w l_i - \sum_{j=1}^{N} p_j m_{ji} < 0 \tag{A.12}$$

In this case, I have the LHS of Equation (A.12) as

$$\begin{aligned}
\mathbf{LHS} &= \left(\xi_i^l - \alpha_i \theta_i^l - \sum_{j=1}^{N} \omega_{ji} \theta_{ji}^m\right) p_i y_i \\
&\approx \xi_i^l - \alpha_i \theta_i^l - \sum_{j=1}^{N} \omega_{ji} \theta_{ji}^m \\
&= \xi_i^l - \frac{\alpha_i}{1+\mu_i} - \sum_{j=1}^{N} \frac{\omega_{ji}}{\sqrt{\left(1 - \kappa \bar{d}_j + \left(1 - \bar{d}_j\right) \mu_i\right)^2 + \frac{1-\kappa}{\varphi_j} \left(\mu_j - \mu_i\right) \left(\kappa + \mu_i\right)}}
\end{aligned}$$

Let $\bar{\xi}_i^l = \inf \left\{ \frac{\alpha_i}{1+\mu_i} - \sum_{j=1}^{N} \frac{\omega_{ji}}{\sqrt{\left(1-\kappa\bar{d}_j + \left(1-\bar{d}_j\right)\mu_i\right)^2 + \frac{1-\kappa}{\varphi_j}(\mu_j - \mu_i)(\kappa + \mu_i)}} \right\}$. Then, Equation (A.12) holds for $\xi_i^l < \bar{\xi}_i^l$. Second, I want to show that there exists $\underline{\xi}_i^l$ such that for all $\xi_i^l > \underline{\xi}_i^l$,

$$\xi_i^l y_i > \sum_{j=1}^{N} m_{ij} \tag{A.13}$$

By the market clearing condition, Equation (A.13) becomes

$$\xi_i^l y_i > y_i - c_i$$

Given $y = \left(\mathbf{I} - \Omega' \diamond \Theta_m'\right)^{-1} \nu = \tilde{\nu} c$, Equation (A.13) becomes

$$\xi_i^l > 1 - \frac{\nu_i}{\tilde{\nu}_i}$$

Let $\underline{\xi}_i^l = \sup \left\{ 1 - \frac{\nu_i}{\tilde{\nu}_i} \right\}$. Then, Equation (A.13) holds for $\xi_i^l > \underline{\xi}_i^l$. Under some appropriate assumption for parameters, I have $\bar{\xi}_i^l > \underline{\xi}_i^l$.

A.6.6 Proof of Proposition 4

Combining Equation (1.12) with (1.13), I have

$$p_i y_i = \left(p_i z_i \left(\frac{\omega_{ji}\theta_{ji}^m}{p_j} \right)^{\omega_{ji}} \left(\frac{\alpha_i \theta_i^l}{w} \right)^{\alpha_i} \right)^{\frac{1}{1-\alpha_i-\sum_{j=1}^N \omega_{ji}}} \tag{A.14}$$

Taking logarithm of Equation (A.14) and stacking across all sectors, I have

$$\mathbf{D}_\pi (\log p_t + \log y_t) = \log z_t + \left(\mathbf{I} - \Omega'\right) \log p_t + \mathbf{M}_\omega (\log \omega + \log \theta_t^m) + \mathbf{D}_\alpha \left(\log \alpha + \log \theta_t^l - \mathbf{1} \log w \right) \tag{A.15}$$

The optimal condition for the household's problem is

$$\eta c = w \tag{A.16}$$

Taking logarithm of Equation (1.22) and stacking across all sectors, I have

$$\log p_t + \log y_t = \log \tilde{\nu}_t + \mathbf{1} \log c \tag{A.17}$$

Replacing $\log p_t$ with Equation (A.17) and w with Equation (A.16), I have

$$\begin{aligned} \mathbf{D}_\pi (\log \tilde{\nu}_t + \mathbf{1} \log c) &= \log z_t + (\mathbf{I} - \Omega') (-\log y_t + \log \tilde{\nu}_t + \mathbf{1} \log c) \\ &\quad + \mathbf{M}_\omega (\log \omega + \log \theta_t^m) + \mathbf{D}_\alpha \left(\log \alpha + \log \theta_t^l - \mathbf{1} (\log c + \log \eta) \right) \end{aligned}$$

Let $\log \mathcal{C} = \mathbf{M}_\omega \log \omega + \mathbf{D}_\alpha \log \alpha - \mathbf{D}_\alpha \mathbf{1} \log \eta$. Then I have

$$\log y_t = (\mathbf{I} - \Omega')^{-1} \left(\log \mathcal{C} + \log z_t + \mathbf{M}_\omega \log \theta_t^m + \mathbf{D}_\alpha \log \theta_t^l + (\mathbf{I} - \Omega' - \mathbf{D}_\pi) \log \tilde{\nu}_t \right) \tag{A.18}$$

where $(\mathbf{D}_k + \mathbf{D}_\alpha)\mathbf{1} = (\mathbf{I} - \Omega')\mathbf{1}$. Taking the first difference of Equation (A.18) results Equation 1.23. Moreover, because $\nu' \log p_t = 0$ and $\nu' \mathbf{1} = 1$, then we have

$$\begin{aligned} \log c &= \nu' (\log y_t - \log \tilde{\nu}_t) \\ &= \nu' (\mathbf{I} - \Omega')^{-1} \left(\log \mathcal{C} + \log z_t + \mathbf{M}_\omega \log \theta_t^m + \mathbf{D}_\alpha \log \theta_t^l - \mathbf{D}_\pi \log \tilde{\nu}_t \right) \end{aligned} \tag{A.19}$$

A.6.7 Proof of Proposition 5

Let δ_i be the ith row of matrix $(\mathbf{I}-\Omega')^{-1}$. Then I have

$$\Delta \log y_{it} = \delta_i \Delta \log z_t \tag{A.20}$$

For $\forall\ i, j$, the sample covariance of output growth between sector i and j is

$$\begin{aligned}
\mathbf{cov}\left(\Delta \log(y_i), \Delta \log(y_j)\right) &= \frac{1}{T-1}\sum_{t=1}^{T} \Delta \log y_{it} \Delta \log y_{jt} \\
&= \frac{1}{T-1}\sum_{t=1}^{T} \delta_i \Delta \log z_t \Delta \log {z_t}' \delta_j' \\
&= \delta_i \left(\frac{1}{T-1}\sum_{t=1}^{T} \Delta \log z_t \Delta \log {z_t}'\right) \delta_j' \qquad \text{(A.21)}
\end{aligned}$$

where the second equation is due to Equation (A.20). Let $\mathbf{M}_z = \frac{1}{T-1}\sum_{t=1}^{T} \Delta \log z_t \Delta \log {z_t}'$. Then the sample correlation between sector i and j

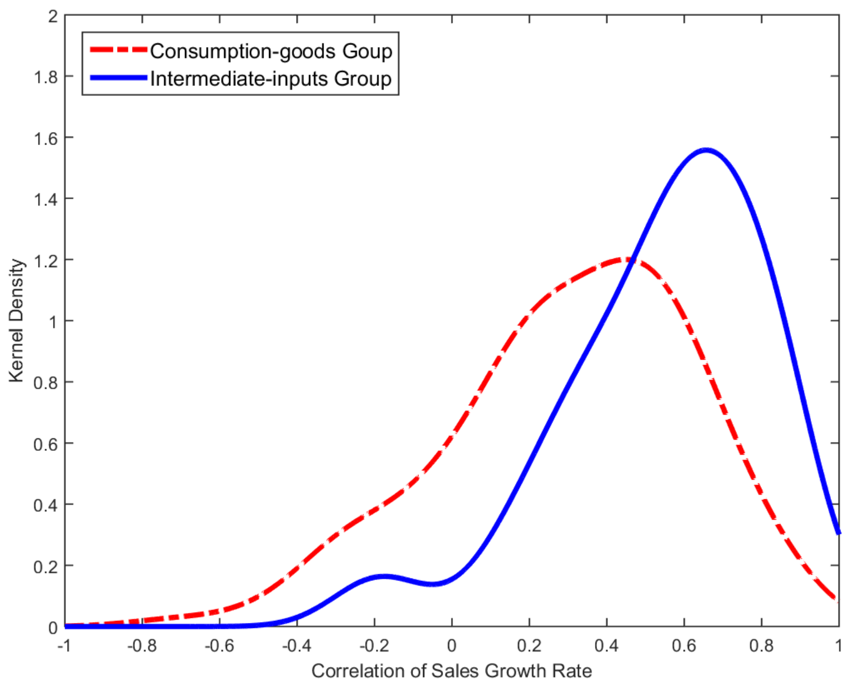
$$\begin{aligned}
\mathbf{corr}\left(\Delta \log(y_i), \Delta \log(y_j)\right) &= \sqrt{\frac{\delta_i \mathbf{M}_z \delta_j' \delta_i \mathbf{M}_z \delta_j'}{\delta_i \mathbf{M}_z \delta_i' \delta_j \mathbf{M}_z \delta_j'}} \\
&= \sqrt{\frac{\mathbf{tr}\left(\delta_i \mathbf{M}_z \delta_j' \delta_i \mathbf{M}_z \delta_j'\right)}{\delta_i \mathbf{M}_z \delta_i' \delta_j \mathbf{M}_z \delta_j'}} \\
&= \sqrt{\frac{\mathbf{tr}\left(\delta_j \mathbf{M}_z \delta_i' \delta_j \mathbf{M}_z \delta_i'\right)}{\delta_i \mathbf{M}_z \delta_i' \delta_j \mathbf{M}_z \delta_j'}} \\
&= \sqrt{\frac{\delta_j \mathbf{M}_z \delta_i' \delta_j \mathbf{M}_z \delta_i'}{\delta_i \mathbf{M}_z \delta_i' \delta_j \mathbf{M}_z \delta_j'}}
\end{aligned}$$

A.7 Value of Parameters

Table 28: List of Sectors and Characteristics

Industry	Source	Consumption	Input	$\Delta\frac{AR}{S}$	$\Delta\frac{AP}{OC}$	BL_Shock
Agriculture, forestry, fishing, and hunting	BEA	17%	82%	NA	NA	0.70
Mining	BEA	0%	138%	NA	NA	0.64
Utilities	BEA	45%	55%	NA	NA	0.56
Construction	BEA	0%	15%	NA	NA	0.64
Food	QFR	56%	44%	-9%	-1%	0.60
Beverage and Tobacco Products	QFR	93%	16%	-20%	-46%	0.55
Textile Mills and Textile Product Mills	QFR	43%	79%	0%	-14%	0.54
Apparel and Leather Products	QFR	534%	50%	-6%	-1%	0.48
Wood Products	QFR	4%	106%	-1%	4%	0.65
Paper	QFR	13%	91%	1%	4%	0.57
Printing and Related Support Activities	QFR	3%	97%	-6%	-8%	0.42
Petroleum and Coal Products	QFR	37%	73%	-27%	-29%	0.51
All Other Chemicals	QFR	33%	65%	-9%	5%	0.54
Plastics and Rubber Products	QFR	13%	94%	-11%	0%	0.49
Nonmetallic Mineral Products	QFR	7%	106%	-5%	-3%	0.53
Foundries	QFR	1%	100%	-6%	2%	0.47
Fabricated Metal Products	QFR	4%	99%	-6%	-15%	0.54
Machinery	QFR	3%	42%	-13%	-3%	0.52
All Other Electronic Products	QFR	16%	57%	-10%	-10%	0.58
Electrical Equipment, Appliances, and Components	QFR	28%	78%	-7%	-1%	0.58
Furniture and Related Products	QFR	55%	39%	-4%	-6%	0.55
Miscellaneous Manufacturing	QFR	64%	46%	-5%	0%	0.53
Iron, Steel, and Ferroalloys	QFR	0%	120%	-11%	-27%	0.51
Computer and Peripheral Equipment	QFR	51%	59%	-1%	0%	0.57
Basic Chemicals, Resins, and Synthetics	QFR	0%	93%	-12%	-14%	0.53
Motor Vehicles and Parts	QFR	41%	48%	1%	-12%	0.48
Nonferrous Metals	QFR	0%	130%	-21%	-20%	0.47
Communications Equipment	QFR	10%	61%	-13%	-9%	0.58
Pharmaceuticals and Medicines	QFR	93%	45%	3%	24%	0.57
Aerospace Products and Parts	QFR	9%	33%	4%	3%	0.59
Wholesale Trade	QFR	32%	44%	-2%	-6%	0.52
Food and Beverage Stores	QFR	99%	1%	-22%	-7%	0.59
Clothing and General Merchandise Stores	QFR	96%	3%	-28%	-11%	0.55
All Other Retail Trade	QFR	82%	13%	-6%	-10%	0.60
Transportation and warehousing	BEA	26%	61%	NA	NA	0.58
Information	BEA	37%	45%	NA	NA	0.53
Professional and business services	BEA	7%	61%	NA	NA	0.57
Management of companies and enterprises	BEA	0%	100%	NA	NA	0.52
Administrative and waste management services	BEA	9%	91%	NA	NA	0.57
Educational services, health care, and social assistance	BEA	93%	6%	NA	NA	0.56
Health care and social assistance	BEA	99%	1%	NA	NA	0.43
Arts, entertainment, and recreation	BEA	74%	24%	NA	NA	0.62
Accommodation and food services	BEA	79%	21%	NA	NA	0.67
Other services, except government	BEA	73%	28%	NA	NA	0.53

Figure 20: Pairwise Correlation during the Great Recession by Product Usage



Note: Consumption–goods group in which the share of products used as consumption goods is more than the median value across sectors; and Intermediate-inputs group in which the share of products used as consumption goods is less than the median value across sectors. Equation 1.1 is used to calculate the correlation of sales growth rate. The blue solid and red dashed lines represent the densities for the intermediate–inputs and consumption–goods group respectively.

Table 29: Sales Growth Rate Correlation: Stylized Fact II

	Mean	Median	Std	Skewness	KS Statistics
Consumption–goods Group					
Before the Great Recession	0.07	0.09	0.42	-0.13	0.17 (0.00)
During the Great Recession	0.30	0.34	0.33	-0.49	
After the Great Recession	-0.01	0.01	0.41	-0.04	0.20 (0.00)
Intermediate–inputs Group					
Before the Great Recession	0.08	0.08	0.38	-0.08	0.17 (0.00)
During the Great Recession	0.47	0.57	0.36	-1.04	
After the Great Recession	0.05	0.07	0.42	-0.07	0.20 (0.00)
KS Test across Groups during the Great Recession					
Intermediate vs Consumption					0.12 (0.00)

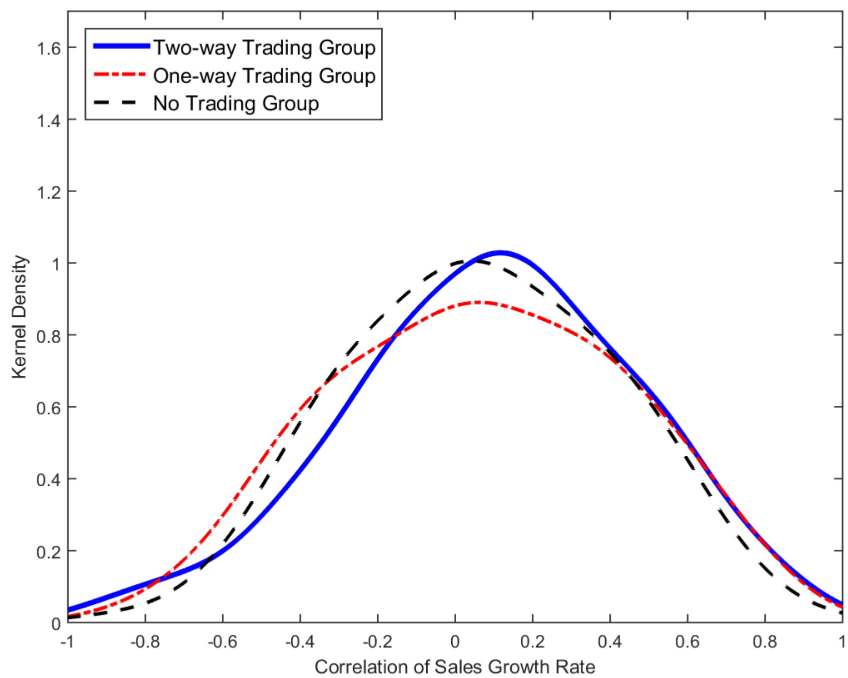
Notes: All kernel densities f are calculated on unit interval $[-1, 1]$ with bandwidth 0.001. *p-value* for the KS statistics is reported in the parentheses. The critical values of KS statistics at 0.1%, 1%, and 5% significance level are respectively 0.0616, 0.0515 and 0.0430 in this case.

Table 30: Results for the Regression A.1

	(1)	(2)	(3)	(4)	(5)
$\mathbf{D}^{tc}$	.182***	.27**	.183***	.263**	.272**
	(.0424)	(.0921)	(.0458)	(.0908)	(.092)
$\mathbf{D}^{tf}$	.138***	.181***	.0366	.0833	.079
	(.0416)	(.0508)	(.0488)	(.0558)	(.0553)
$\mathbf{D}^{bl}$	.0228	.0107	-.0983	$-.135^{+}$	$-.13^{+}$
	(.0401)	(.0503)	(.0693)	(.0748)	(.0741)
$\mathbf{D}^{tc} \times \mathbf{D}^{tf}$		$-.184^{+}$		-.218*	-.211*
		(.109)		(.111)	(.111)
$\mathbf{D}^{tc} \times \mathbf{D}^{bl}$		.00416		.0492	.0529
		(.132)		(.135)	(.141)
Obs	475	475	475	475	475
Method	OLS	OLS	OLS	OLS	Tobit
Sectoral Char	No	No	Yes	Yes	Yes
R^2	.0686	.0749	.135	.145	

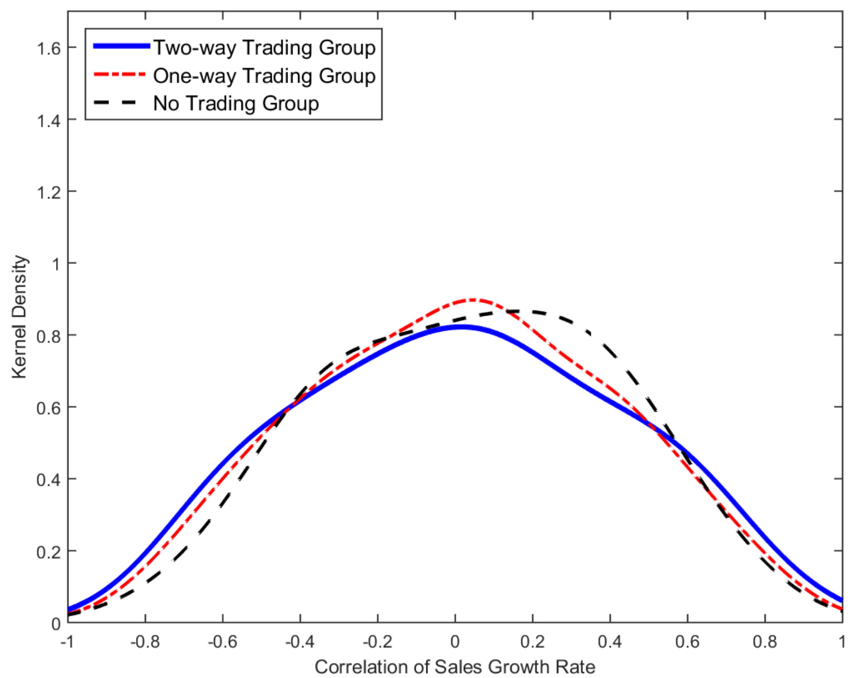
Notes: $\mathbf{D}^{tc}$, $\mathbf{D}^{tf}$, and $\mathbf{D}^{bl}$ are respectively defined in Equation 1.2, 1.5, and 1.6, and X contains sectoral characteristics such as the share of intermediate inputs share over the total output value, extensive margin of sectoral connectedness, intensive margin of sectoral connectedness, and output share for final usage. Standard errors in parentheses. "+", "*", "**", and "***" respectively stand for *p–value* smaller than 10%, 5%, 1%, and 0.1%.

Figure 21: Pairwise Correlations before the Great Recession by Types of Interconnectedness



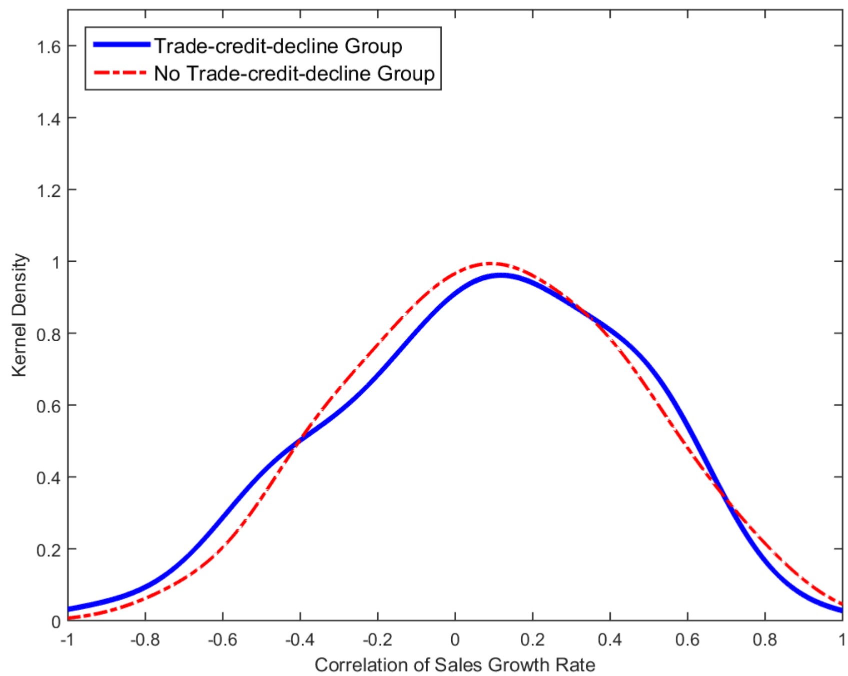
Note: Two–way trading group where two sectors are both intermediate inputs provider and purchaser to each other; one–way trading group where only one sector purchases intermediate inputs from the other but not other way around; and no trading group where no intermediate input is traded between two sectors. There are respectively 381, 410, and 155 pairs in each group. Equation 1.1 is used to calculate the correlation of sales growth rate. The blue solid, red dashed, and black dotted lines represent the densities for the two–way, one–way and no–trade group respectively.

Figure 22: Pairwise Correlations after the Great Recession by Types of Interconnectedness



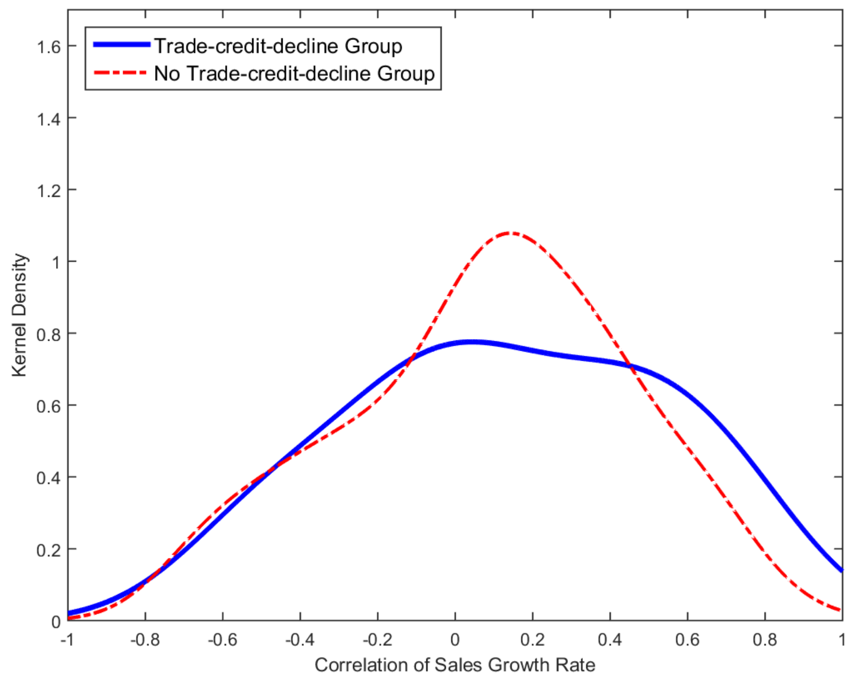
Note: Two–way trading group where two sectors are both intermediate inputs provider and purchaser to each other; one–way trading group where only one sector purchases intermediate inputs from the other but not other way around; and no trading group where no intermediate input is traded between two sectors. There are respectively 381, 410, and 155 pairs in each group. Equation 1.1 is used to calculate the correlation of sales growth rate. The blue solid, red dashed, and black dotted lines represent the densities for the two–way, one–way and no–trade group respectively.

Figure 23: Pairwise Correlation before the Great Recession: the Change in Trade Credit



Note: A pair is considered as experiencing trade credit decline during the Great Recession if both the intensity of the upstream sector's trade credit provision declined more than 6.3% and the intensity of the downstream sector's trade credit reception declined more than 6.0%. Otherwise, the pair is categorized into the control group. The blue solid and red dashed lines respectively represent the densities of group experiencing the decline in trade credit and the counterpart.

Figure 24: Pairwise Correlation After the Great Recession: the Change in Trade Credit



Note: A pair is considered as experiencing trade credit decline during the Great Recession if both the intensity of the upstream sector's trade credit provision declined more than 6.3% and the intensity of the downstream sector's trade credit reception declined more than 6.0%. Otherwise, the pair is categorized into the control group. The blue solid and red dashed lines respectively represent the densities of group experiencing the decline in trade credit and the counterpart.

Table 31: Value of Parameters

	Sectors	α	ν	φ	$\bar{d}$	ρ	σ^e	$\bar{e}$
1	Agriculture	0.12	0.01	0.02	0.43	0.75	0.01	0.13
2	Mining	0.13	0.00	0.02	0.89	0.81	0.03	0.15
3	Utilities & Construction	0.28	0.03	0.03	0.46	0.86	0.05	0.52
4	Durable goods	0.18	0.13	0.03	0.55	0.72	0.05	0.49
5	Nondurable goods	0.16	0.09	0.03	0.48	0.80	0.04	0.45
6	Wholesale	0.34	0.05	0.03	0.44	0.69	0.05	0.50
7	Retail	0.38	0.14	0.01	0.42	0.21	0.05	0.49
8	Transportation	0.30	0.03	0.03	0.30	0.73	0.05	0.57
9	Information	0.22	0.05	0.04	0.64	0.34	0.03	0.35
10	Professional services	0.42	0.02	0.02	0.65	0.70	0.01	0.88
11	Administrative services	0.48	0.01	0.03	0.37	0.30	0.03	0.79
12	Educational services	0.53	0.03	0.03	0.25	0.88	0.06	0.65
13	Health care	0.50	0.23	0.02	0.30	0.76	0.06	0.63
14	Recreation services	0.34	0.11	0.02	0.21	0.86	0.05	0.50
15	Other services	0.41	0.06	0.01	0.37	0.66	0.05	0.55

Appendix B

Appendix for Chapter 2

B.1 Data

The NLSY79 interviews respondents annually from from 1979 to 1992 and biennially after 1992. In every interview year, it records up to five jobs held by respondents and the corresponding start and end weeks (Concept: Start Week of Job # and Stop Week of Job #). In some cases, the same job is assigned as two different jobs because they are recorded in different interview years. We treat these two jobs as the same one if the respondents identify the latter job as being with the same employer as the former one (Concept: Previous Job Number at Last Interview), and the latter one starts within four weeks after the former one ends. To identify full-time jobs, we screen out all jobs in which employees work less than 30 hours (Concept: Hours Per Week Worked). For the cases where work hours are not available, we only consider the job to be full time if it lasts at least 12 weeks.

To construct our sample, we first screen out all military subsamples and all sample dropouts in 1990 (Concept: Sample Identification Code), and all females (Concept: Sex of Respondent). Then we restrict our sample according to three types of the respondents' education levels (Concept: Highest Education Level completed as the May 1st of the Survey Year); namely, high school graduation, some college education but no degree, and college degree. These subsets have 1,655, 710, and 652 observations, respectively. We drop all observations where no job information is provided. Next, we focus on males who graduate college at or before age 23, which has 428 respondents.

Finally, we use two approaches to construct annually representative wage (Concept:

Hourly Rate of Pay Job #). First, we consider all full-time jobs held by each respondent in each year, and calculate the weighted average hourly wage using work-week share of each job as the weight. Second, we only consider hourly wages of the *CPS job*. We first identify the CPS job, which is the one with job number 1 for most cases. An exception is the case for some respondents in 1980-1992. To fix this, we use the identifier of the current job (Concept: Is Job # Same as Current Job?) to determine if the current job is the CPS job. If the wage of the CPS job is not available, we find the next most recent job with available wage. All hourly wage rates are in 2009 dollars using the U.S. GDP deflator.

B.2 Wage paths before college graduation

Figure 25 plots the average wage before and after college graduation. The horizontal axis indicates the years before and after graduation ("0" means the graduation time). We can see that the wages are in general stagnant before graduation, but start to rise one year before graduation. In Section 2.3.2, we see that this transition pattern is also consistent with the change in the occupation mix.

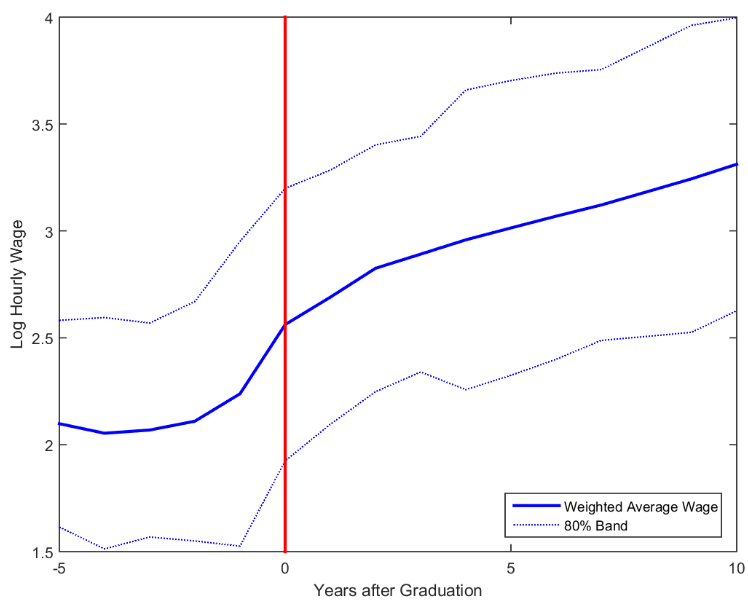
B.3 Wage regressions

In this section, we examine whether holding a job during college has a long-term effect on future wage paths. We consider the following regression:

$$\log W_i = \alpha_0 + \alpha_1 D_i + \beta' X_i + \gamma' Y + \epsilon_i, \tag{B.1}$$

where W_i is the weighted average wage at age of 30 (or 35); D_i is a dummy variable, which is equal to 1 if the respondent held the summer/temporary/regular long-term jobs during college; X_i are a vector of characteristics control variables for the respondents and their families; and Y is a collection of year dummy variables. Characteristics control variables are respondents' AFQT composite math and verbal scores, races, whether both parents were working at the beginning of the survey, whether they worked for full time, whether both parents were on record of the survey, whether both parents lived separately, the years of highest education years received by both parents, the SMSA code where the respondent graduated at the year before college graduation, the region dummy where the respondent

Figure 25: Average wage path before and after college graduation



Notes: The middle line is the average log hourly wages before and after graduation. The 80% confidence band is also shown.

lived at the year before college graduation, and whether the respondent lived in a rural or urban area at the year before college graduation.

To address the issue of selection bias, we follow Ruhm (1997) and use two approaches. First, a "treatment-effects" model is considered, where the "treatment" is the choice of whether or not to work at a certain job during college. We first run a Probit model where the dependent variable is a dummy of whether to work during college and the independent variables are the characteristics control variables. Then we calculate the inverse Mills ratio for respondents who worked during college, and then we include this inverse Mills ratio in the second stage, where geographic variables are not included for the exclusion restriction. Second, we conduct an instrumental variable (2SLS) estimation where geographic variables are used to identify the model.

Table 32 displays the results for wage at the age of 30 and 35. The work experience dummy, which is of our interest, is not statistically significant in all cases. In Section 2.3.2 and Appendix B.2, we observe that the jobs just before the college graduation have different characteristics from the other JBCC. To check robustness, we repeat this exercise for the jobs held during the final year of college. Table 33 shows the result. Once again, the work experience dummy is not statistically significant in all cases. Thus we cannot reject the hypothesis that JBCC do not have any influence on future wages.

B.4 Additional figures for Section 2.3.2

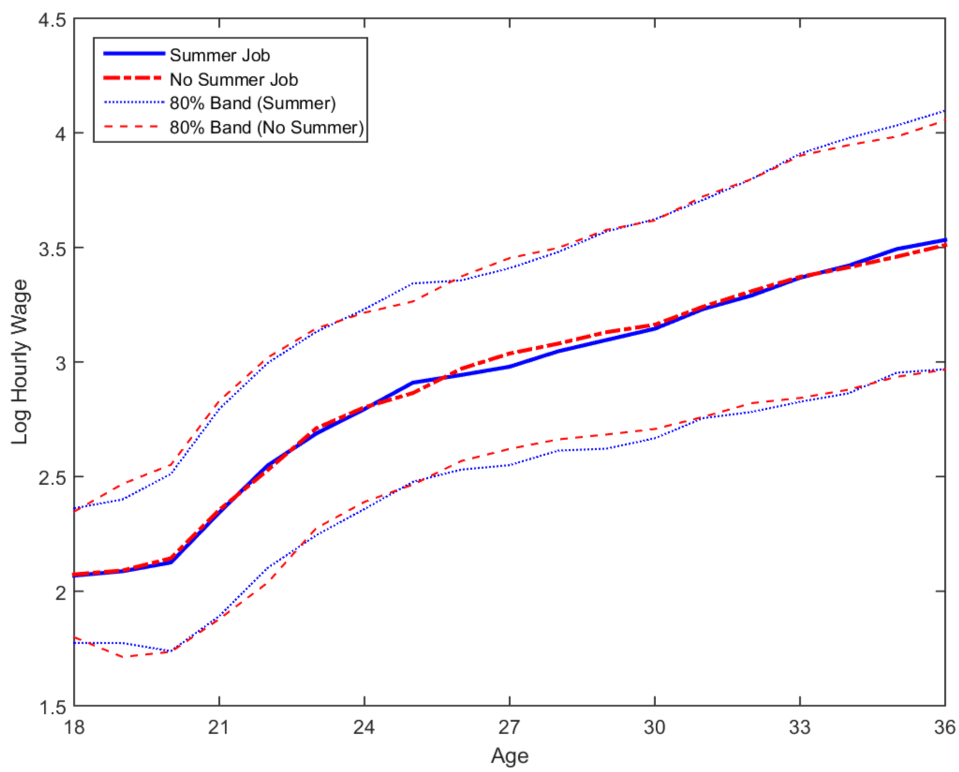
In addition to Figure 14, we consider two different subdivisions of the sample. Figure 26 plots the paths for the weighted average of wages for the workers who held summer jobs during school versus workers who did not. Summer jobs are defined as jobs held between May 1 and August 31 during the years the workers are in school. Figure 27 plots the paths for the weighted average of wages for the workers who held a temporary job during school versus the workers who did not, where a job is recognized as temporary if it is held for less than 12 weeks during school other than summer time. Figure 28 plots the paths for the weighted average of wages for the workers who held jobs that are neither summer jobs nor temporary jobs (we call them regular long-term jobs) versus the workers who did not. Figure 29 plots the paths for the weighted average of wages for the workers who held jobs during the final year of college versus the workers who did not. The results are similar to Figure 14: the wage paths are very similar across these subsamples.

Table 32: Wage equation

	OLS			Treatment Model			IV Estimation (2SLS)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Wage at Age 30									
D^{sj}	0.0015			−0.44			−0.49		
	(0.058)			(0.39)			(0.40)		
D^{tj}		0.012			0.042			0.023	
		(0.075)			(0.30)			(0.35)	
D^{rj}			−0.039			0.20			−0.77
			(0.066)			(0.54)			(0.78)
Obs	358	358	358	358	358	358	358	358	358
R^2	0.11	0.11	0.11	0.10	0.09	0.09	0.10	0.09	0.09
Wage at Age 35									
D^{sj}	−0.011			−0.29			−0.16		
	(0.063)			(0.38)			(0.40)		
D^{tj}		−0.038			−0.21			−0.024	
		(0.081)			(0.32)			(0.38)	
D^{rj}			0.011			−0.41			−0.92
			(0.071)			(0.51)			(0.67)
Obs	340	340	340	340	340	340	340	340	340
R^2	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19

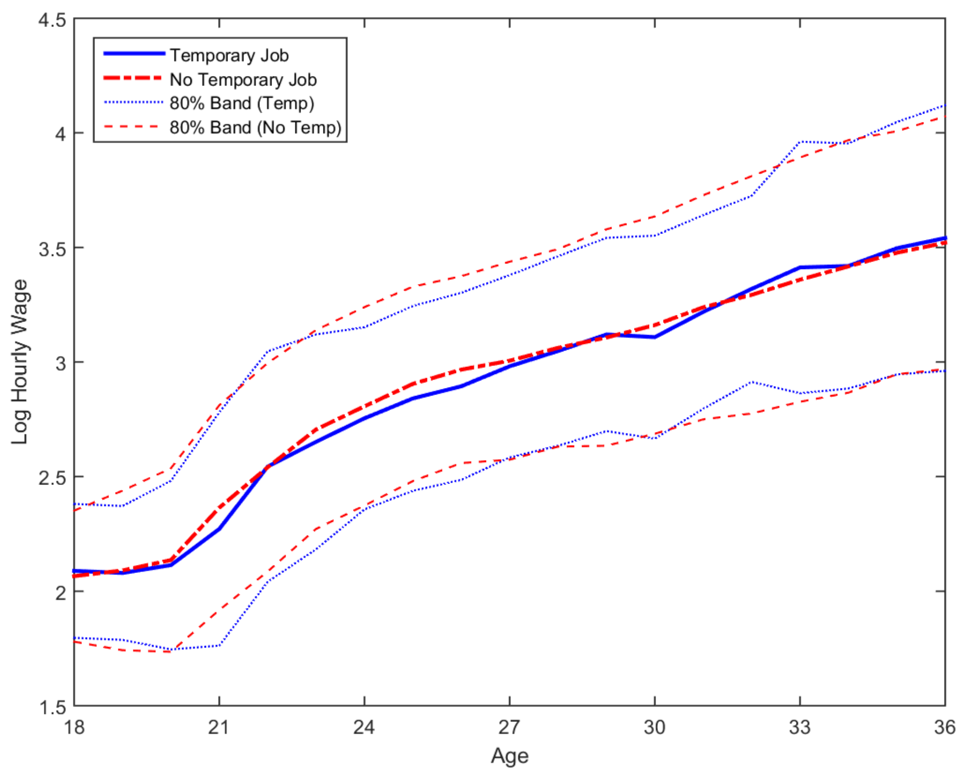
Note: The table shows the estimated coefficients in Equation B.1.

Figure 26: Average wage paths for samples with and without summer jobs (2009 dollar)



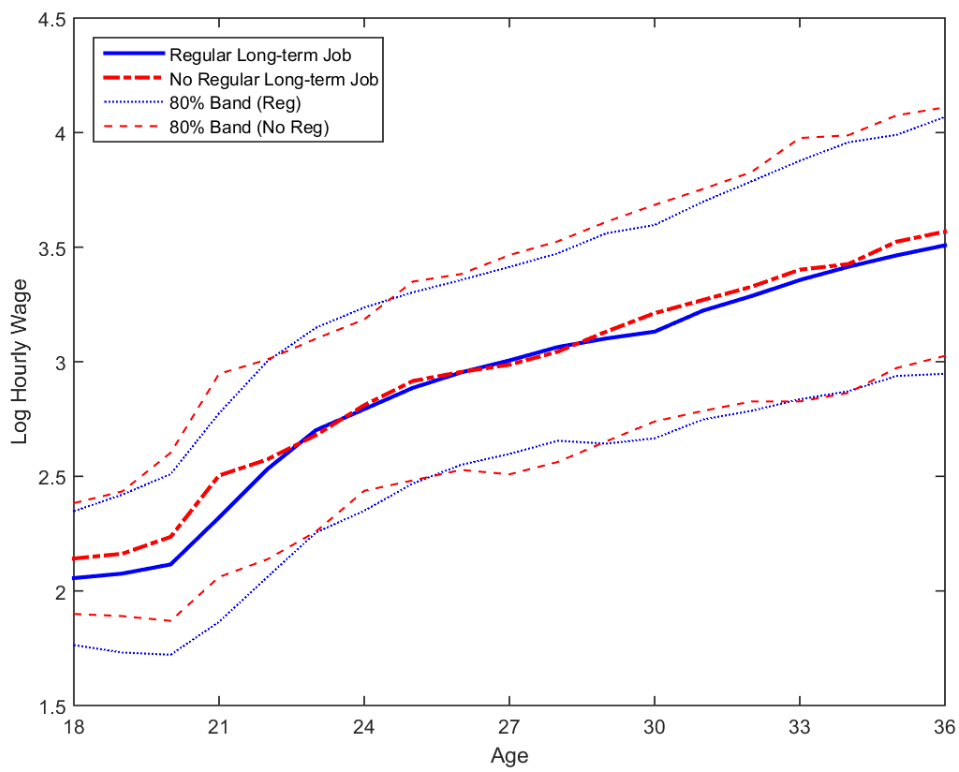
Notes: The middle lines are the average log hourly wages for the samples with summer jobs (solid line) and without summer jobs (dash-dot line). The 80% confidence bands are also shown.

Figure 27: Average wage paths for samples with and without temporary jobs (2009 dollar)



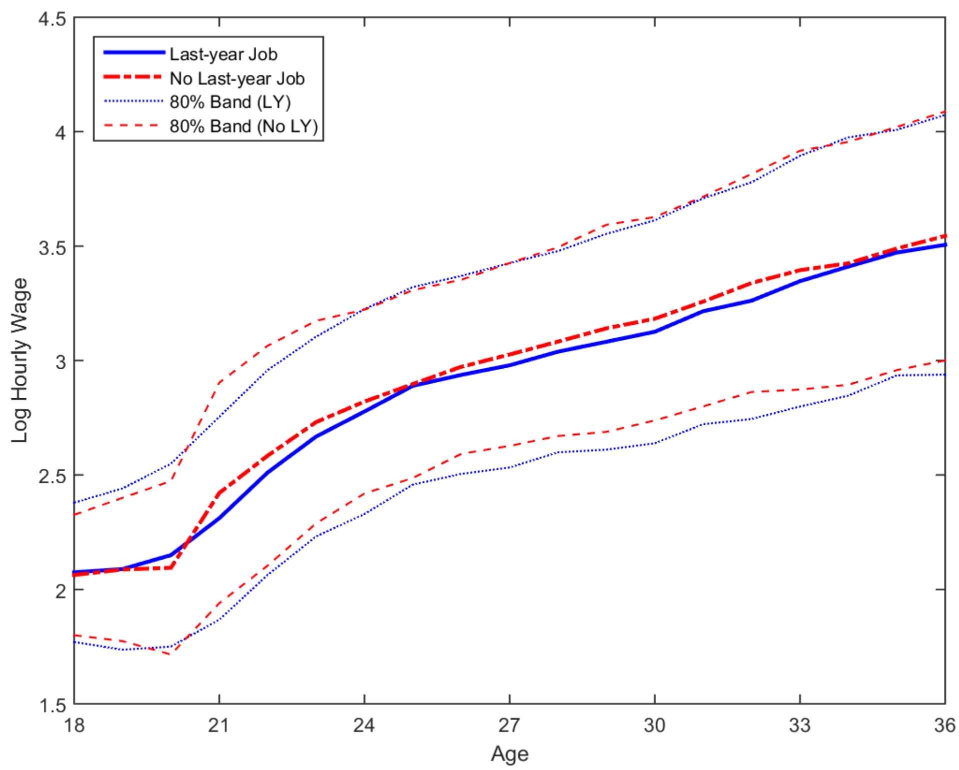
Notes: The middle lines are the average log hourly wages for the samples with temporary jobs (solid line) and without temporary jobs (dash-dot line). The 80% confidence bands are also shown.

Figure 28: Average wage paths for samples with and without regular long-term jobs (2009 dollar)



Notes: The middle lines are the average log hourly wages for the samples with regular long-term jobs (solid line) and without regular long-term jobs (dash-dot line). The 80% confidence bands are also shown.

Figure 29: Average wage paths for samples with and without jobs at the last year of college (2009 dollar)



Notes: The middle lines are the average log hourly wages for the samples with jobs at the last year of college (solid line) and without jobs at the last year of college (dash-dot line). The 80% confidence bands are also shown.

Table 33: Wage equation with working experience at the final year of college

	Age 30			Age 35		
	(1) OLS	(2) Treatment	(3) IV (2SLS)	(4) OLS	(5) Treatment	(6) IV (2SLS)
D^{lj}	−0.051	−0.35	−0.39	0.072	−0.42	−0.40
	(0.057)	(0.33)	(0.34)	(0.061)	(0.30)	(0.30)
Obs	358	358	358	340	340	340
R^2	0.11	0.10	0.10	0.20	0.20	0.19

Notes: The table shows the estimated coefficients in regression (1). The work experience dummy is for the jobs held at the final year of college.

Table 34: Probability of staying in the same occupation

	10 Categories	4 Categories
Transition	21.0%	33.9%
Before	37.3%	50.8%
After	46.7%	60.0%

Note: The table reports the probability of staying in the same occupation from the last job before college completion to the first job afterward, from the second last to the last job before college completion, and from the first to the second job after college completion.

B.5 Occupational switch

Table 34 reports the probability of staying in the same occupation from the last job before college completion to the first job afterward, from the second last to the last job before college completion, and from the first to the second job after college completion. Also, Table 35 shows the wage change from the last job before college graduation to the first job afterward. We separately report the statistics of wage changes for respondents when staying in the same occupation category and switching from one category to another.

Table 35: Summary statistics: wage growth during transition

Transition	Obs	Mean	Std	10%	Median	90%
10 Categories						
On Diagonal	24	43.9%	93.8%	−43.0%	14.8%	152.7%
Off Diagonal	99	109.1%	167.9%	−22.3%	51.0%	318.3%
4 Categories						
On Diagonal	37	67.0%	111.3%	−29.2%	18.9%	225.4%
Off Diagonal	86	109.0%	173.4%	−28.0%	51.9%	315.0%

Note: The table shows the wage change from the last job before college graduation to the first job afterward. "On diagonal" reports the wage changes for respondents when staying in the same occupation category and "off diagonal" reports the case of switching from one category to another.

Table 36: Distribution of Industry: Before and After

		Before		**After**	
Group	Categories	Proportion	Wage	Proportion	Wage
1	Agriculture, Forestry, and Fisheries	5.8%	7.0	2.1%	8.7
2	Mining, Utility and Construction	10.6%	9.0	5.2%	15.2
3	Durable goods	7.6%	10.2	6.8%	16.3
4	Nondurable goods	5.8%	8.3	7.6%	12.4
5	Wholesale and Retail	24.9%	8.5	18.5%	11.6
6	Service (high end)	27.3%	7.7	48.3%	15.9
7	Service (low end)	18.0%	8.3	11.5%	11.7

Note: The table shows the distribution and average wages of different industries, before and after college graduation.

Table 37: Transition Matrix across Industry Categories

From \To	1	2	3	4	5	6	7
1	33.3	0.0	0.0	33.3	0.0	33.3	0.0
2	11.1	22.2	0.0	11.1	0.0	44.4	11.1
3	0.0	18.2	18.2	9.1	18.2	36.4	0.0
4	0.0	0.0	16.7	16.7	16.7	50.0	0.0
5	3.3	3.3	6.7	0.0	33.3	40.0	13.3
6	2.0	8.2	6.1	8.2	2.0	57.1	16.3
7	0.0	4.2	8.3	4.2	20.8	45.8	16.7

Note: The table shows the industry transition matrix between the last job before college graduation and the first job after college graduation.

B.6 Industry transitions

In Tables 36 and 37, we repeat the same exercises as in Section 2.3.2 for industry categories rather than occupations. We do not see differences as strong as in the case of occupations.

B.7 Continuous measurement for occupation distance

Here we create a continuous measurement of occupational distance to examine the difference of occupational choices before and after college graduation. NLSY79 provides three types of information about the respondents' occupations. The first is 1970 Census codes associated with each of the first five jobs in each calender year (Occupation (Census 3 Digit, 70 Codes) Job #). The second is 1980 Census codes associated with identified CPS jobs in each calender year (Concept: Occupation at Current Job/Most Recent Job (80 Census 3 Digit) CPS Item). The third is 2000 Census codes associated with identified CPS jobs in each calender year since 2000 (Occupation (Census 4 Digit, 00 Codes) Job #). To obtain as much information as possible, we choose occupation variables with 1970 Census codes.

The Dictionary of Occupational Titles (DOT) provides skill contents for each occupation, and measures the complexity of tasks with respect to 57 characteristics, including clerical perception, abstract and creative activities, data preference, and communication. However, the occupation codes in the DOT use 1980 Census standard. Denote each occupation in 1980 as o^{80}. The skill content of each occupation can be characterized by a 57-dimensional vector,

$Q^{80}_o = \{q_{o1}, \cdots, q_{oJ}\}$, where $J = 57$. Next, we need to convert 1980 codes into 1970 ones. Census provides a crosswalk between these two standards. In particular, each occupation in the 1970 codes corresponds to one or multiple occupations in the 1980 codes and the associated shares for occupations in the 1980 codes. For example, computer programmers in the 1970 codes are associated with 6% computer systems analysts and scientists and 94% computer programmers in the 1980 code standard. Here we assume that the skill content of each occupation in the 1970 codes can be expressed as a linear combination of the skill content of occupations in the 1980 standard. In particular, for each occupation o' in 1970, $Q^{70}_{o'} = \alpha_{o'1}Q^{80}_1 + \cdots + \alpha_{o'O}Q^{80}_O$, where $\alpha_{o'o}$ is the male population share of occupation o using the 1980 codes in occupation o' using the 1970 code, provided by the crosswalk. Thus the skill content of each occupation in 1970 can also be characterized by a 57-dimensional vector, $Q^{70}_{o'} = \{q_{o'1}, \cdots, q_{o'J}\}$, where $q_{o'j} = \sum_{o=1}^{O} \alpha_{o'o}q_{oj}$ for $\forall\ j$. In total, we have 420 occupations.

With such skill content vectors for 1970 occupations, we use two measures of the distance between two occupations, Euclidean distance and angular separation, as in Gathmann and Schönberg (2010). For two 1970 occupations o and o', Euclidean distance $D^{ED}_{oo'}$ and angular separation $D^{AS}_{oo'}$ are defined as

$$D^{ED}_{oo'} = \sqrt{\sum_{j=1}^{J} (q_{oj} - q_{o'j})^2} \tag{B.2}$$

and

$$D^{AS}_{oo'} = \frac{\sum_{j=1}^{J} q_{oj}q_{o'j}}{\sqrt{\sum_{j=1}^{J} q^2_{oj}}\sqrt{\sum_{j=1}^{J} q^2_{o'j}}}. \tag{B.3}$$

Autor et al. (2003) argue that variables in the DOT are highly correlated so that several variables can be selected to present routine/nonroutine cognitive/manual tasks. In particular, two variables, namely DCP and GED-MATH, measure nonroutine cognitive tasks; STS, FINGDEX, and EYEHAND are respectively employed to measure routine cognitive task, routine manual task, and nonroutine manual task.

Following Autor et al. (2003), we calculate the percentile for each DOT variables across occupations. Table 38 shows the summary statistics of the two measurements defined in (B.2) and (B.3) using a full set of variables and variables chosen in Autor et al. (2003).[1] The

[1]Since in NLSY79 no respondents have reported having occupations in private household workers. Thus we delete this category from 1970 Census occupation. The results are similar if it is included.

Table 38: Continuous Measurement using DOT

	Mean	Std	10%	Median	90%	Corr
All Variables						
D^{ED}	2.99	0.85	1.88	2.97	4.12	
D^{AS}	0.25	0.14	0.09	0.23	0.45	0.97
Variables in Autor et al. (2003)						
D^{ED}	0.86	0.31	0.45	0.85	1.27	
D^{AS}	0.22	0.15	0.05	0.20	0.43	0.81

Note: The table shows the summary statistics of the two measurements defined in (B.2) and (B.3) using a full set of variables and variables chosen in Autor et al. (2003).

two measurements show high correlation, namely 0.97 and 0.81. Moreover, the correlation between two angular separations is 0.68.

Next, we examine the occupational distances using NLSY79. Table 39 displays the distance of the occupations of the last two jobs before college graduation, the last job before graduation and the first one afterward, and the first two jobs after college graduation. Figures 30 and 31 display the kernel density of occupation distance in these three scenarios, using a different full set of variables and variables selected in Autor et al. (2003). We can see that the occupational distances between two consecutive jobs is the largest at the transition after the college. This is consistent with the dramatic change in the occupational mix before and after college graduation in Section 2.3.2.

Moreover, because variables in the DOT are highly correlated with each other, and selection as in Autor et al. (2003) requires more pre-knowledge about variables, we apply the principal component analysis as in Yamaguchi (2012). Figures 32 through 35 display the location of different occupation on two-factor space. Table 40 displays the Euclidean distance of occupations of jobs held before, at college graduation, and after college graduation. Figure 36 displays the kernel density. The main result remains the same: the occupational distance is the greatest at the transition from college.

Table 39: Summary statistics of D^{AS} for NLSY79

	Obs	Mean	Std	10%	Median	90%
All Variables						
Transition	132	0.18	0.12	0.03	0.18	0.32
Before	120	0.11	0.10	0.00	0.09	0.25
After	101	0.14	0.13	0.00	0.13	0.34
Variables in Autor et al. (2003)						
Transition	132	0.17	0.13	0.01	0.15	0.34
Before	120	0.13	0.15	0.00	0.09	0.35
After	101	0.14	0.16	0.00	0.08	0.36

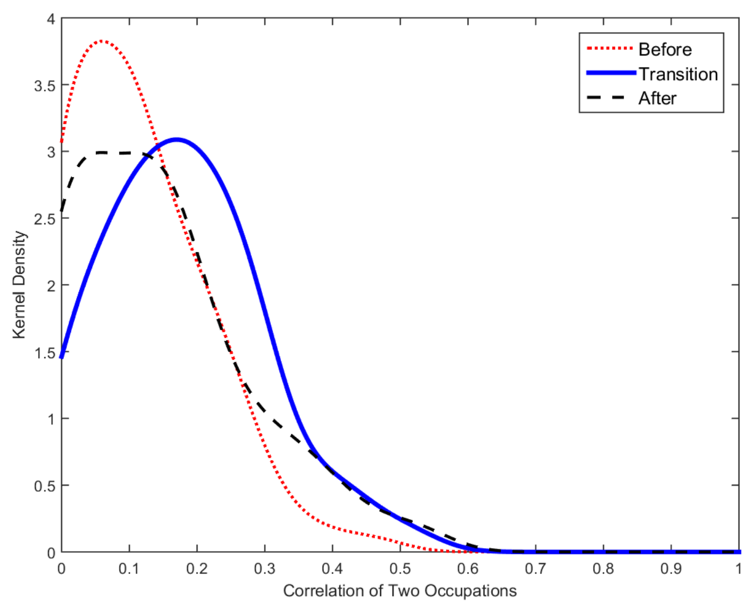
Note: The tables display the distance of the occupations of the last two jobs before college graduation, the last job before graduation and the first one afterward, and the first two jobs after college graduation.

Table 40: Summary statistics of D^{ED} for principal components using NLSY79

	Obs	Mean	Std	10%	Median	90%
Transition	132	1.7	1.0	0.4	1.5	3.0
Before	121	1.2	1.0	0.0	1.1	2.5
After	101	1.3	1.1	0.0	1.3	2.9

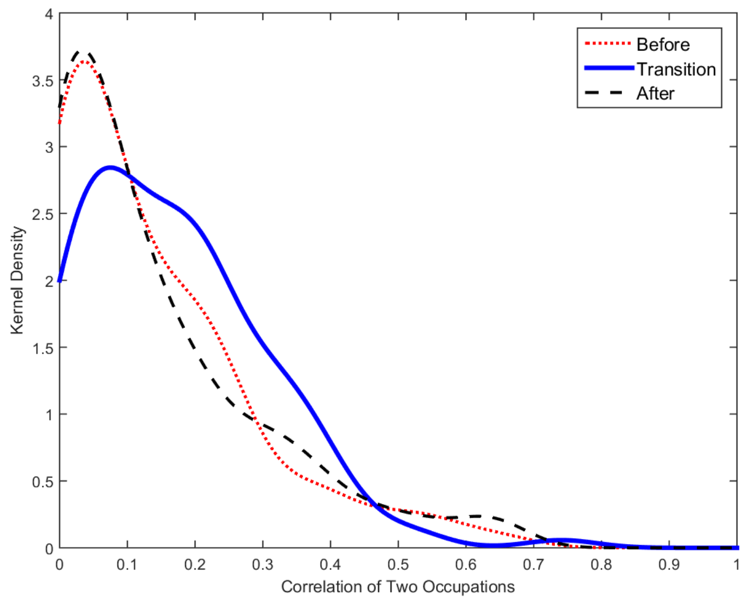
Note: The table shows the summary statistics of the occupational distance using principal components.

Figure 30: Kernel density: Occupation distances D^{AS} using all variables



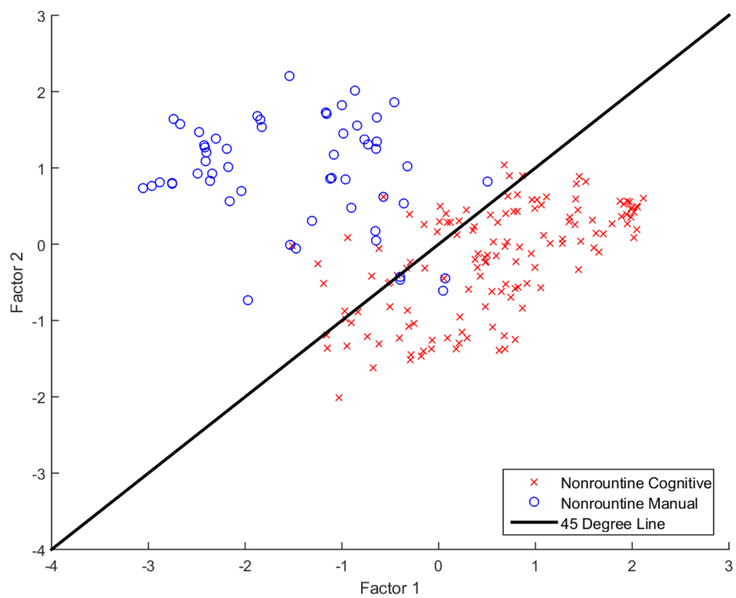
Note: The figure shows the kernel densities of the distance of the occupations of the last two jobs before college graduation, the last job before graduation and the first one afterward, and the first two jobs after college graduation.

Figure 31: Kernel density: Occupation distances D^{AS} using variables in Autor et al. (2003) D^{AS}



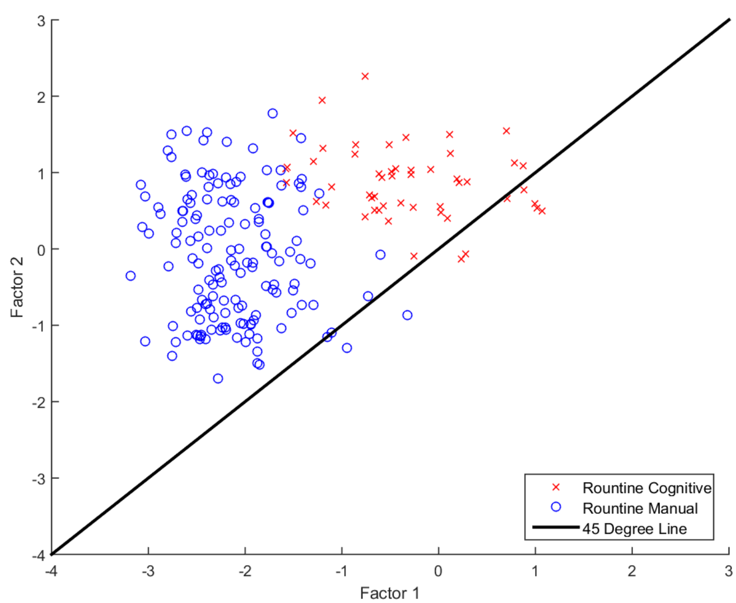
Note: The figure shows the kernel densities of the distance of the occupations of the last two jobs before college graduation, the last job before graduation and the first one afterward, and the first two jobs after college graduation.

Figure 32: Difference between nonroutine cognitive and nonroutine manual



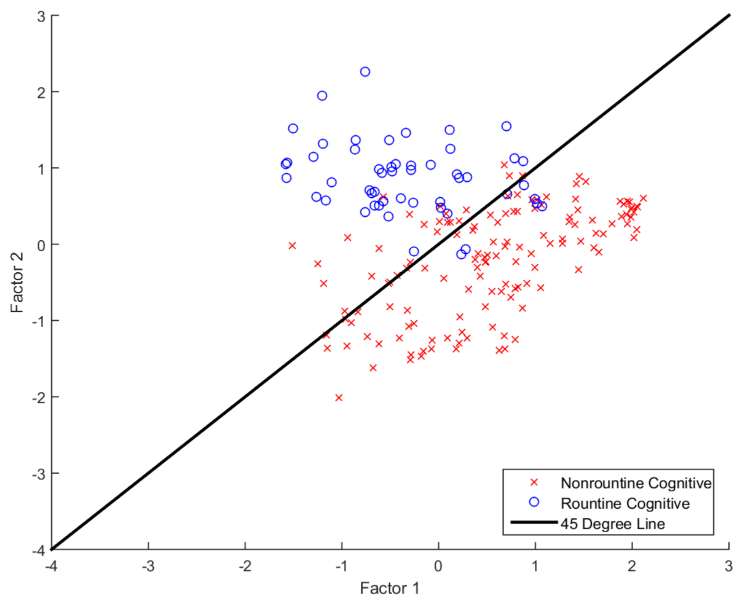
Note: The figure shows the two principal factors for each occupation, with different categories.

Figure 33: Difference between routine cognitive and routine manual



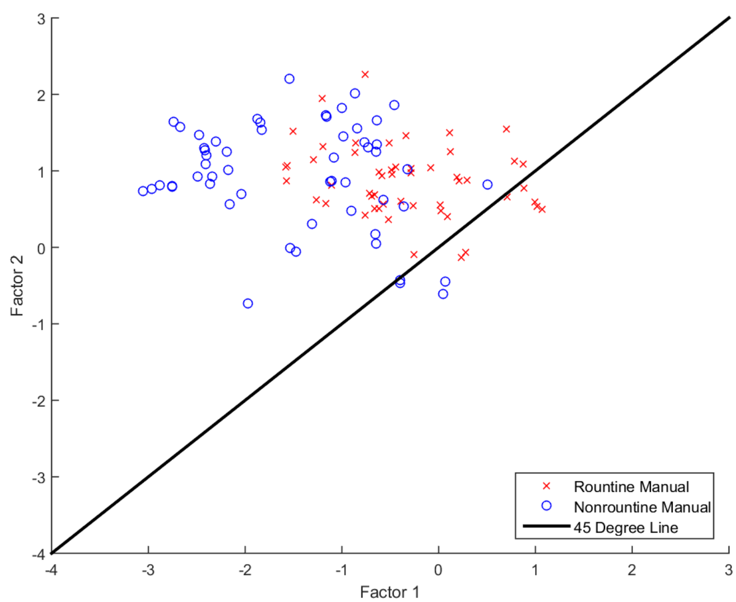
Note: The figure shows the two principal factors for each occupation, with different categories.

Figure 34: Difference between nonroutine and routine cognitive



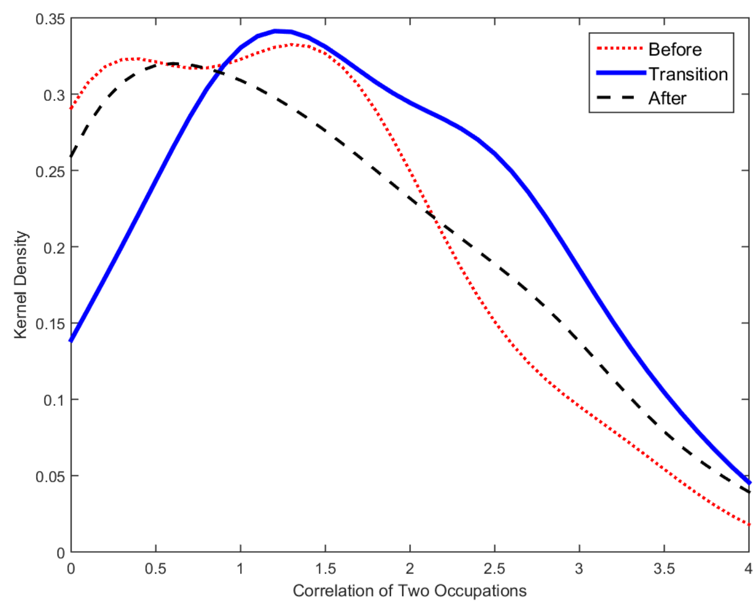
Note: The figure shows the two principal factors for each occupation, with different categories.

Figure 35: Difference between nonroutine and routine manual



Note: The figure shows the two principal factors for each occupation, with different categories.

Figure 36: Kernel density: Occupation difference using principal components D^{ED}



Note: The figure shows the kernel densities of the distance of the occupations of the last two jobs before college graduation, the last job before graduation and the first one afterward, and the first two jobs after college graduation, using the principal components.

Appendix C

Appendix for Chapter 3

C.1 Condensed Version of the Model

In this Appendix we derive the condensed version of the model described in section 3.3.5. We first establish that all prices are constant across periods, from which it follows that real variables are also constant. This allows us to solve the relevant variables of the model as a function of second period productivities. Throughout the process we will drop the time index from those variables that are known to be constant over time.

As a starting point, we know that the assumed monetary policy and the consumption Euler Equation imply that both P^{ik} and c^{ik} are constant. The transfer component $ln\left(g_1^{jl}/g_1^{ik}\right)$ is also constant as it only depends on first period real outputs. To see this, note that by definition $g_1^{ik} = y_1^{ik}/E_0[y_1^{ik}]$. Prior to the realization of any shock all countries are expected to have the same real output, hence $ln\left(g_1^{jl}/g_1^{ik}\right) = ln\ y_1^{jl} - ln\ y_1^{ik}$.

In equilibrium all firms in country (i,k) set the same price and output in all firms is the same, hence goods market equilibrium is described by

$$y_t^{ik} = c_{ik,t}^{ik} + \int\int_0^1 c_{ik,t}^{jl} dj dl \tag{C.1}$$

Substituting the expressions for consumption we have

$$P_t(i,k)y_t^{ik} = \psi_i P^{ik} c^{ik} + S_{ik,t} E_t^{ik} \tag{C.2}$$

where E_t^{ik} is nominal exports of country (i,k), measured in the base currency and given by

$$E_t^{ik} = (1-\psi_i)\int\int_0^1 \frac{1-\psi_j}{1-\bar{\psi}}\frac{P^{jl}}{S_{jl,t}}c^{jl}djdl$$

Integrating E_t^{jl} over j and l we obtain world exports:

$$E_t^W = \int\int_0^1 E_t^{jl}djdl = (1-\bar{\psi})\int\int_0^1 \frac{1-\psi_j}{1-\bar{\psi}}\frac{P^{jl}}{S_{jl,t}}c^{jl}djdl$$

It follows that

$$E_t^{ik} = \frac{(1-\psi_i)}{(1-\bar{\psi})}E_t^W$$

so that (C.2) becomes

$$P_t(i,k)y_t^{ik} = \psi_i P^{ik}c^{ik} + S_{ik,t}\frac{(1-\psi_i)}{(1-\bar{\psi})}E_t^W \tag{C.3}$$

Using the budget constraint of country (i,k), and imposing money and bond market equilibrium, we can write

$$P^{ik}c^{ik} = P_t(i,k)y_t^{ik} + S_{ik}E_t^W\phi_k\left(Q-\bar{\phi}ln\ y_1^{ik}\right) \tag{C.4}$$

where $Q = \int\int_0^1 \phi_l ln\ y_1^{jl}djdl$ and $\bar{\phi} = \int_0^1 \phi_l dl$. If we substitute this expression into (C.3) and rearrange terms we get

$$\frac{P^{ik}c^{ik}}{S_{ik,t}G^{ik}} = \frac{E_t^W}{1-\bar{\psi}} \tag{C.5}$$

where $G_{ik} = 1+\left(\frac{1-\bar{\psi}}{1-\psi_i}\right)\phi_k\left(Q-\bar{\phi}ln\ y_1^{ik}\right)$. Then, using that the previous equation also holds for the base country b and that for this country $S_{b,t}=1$ we obtain the following equivalence

$$\frac{P^{ik}c^{ik}}{G_{ik}S_{ik,t}} = \frac{P^b c^b}{G_b} \tag{C.6}$$

which implies that $S_{ik,t}$ is constant. Now, take logs on both sides of the consumer price index equation and rearrange terms such that

$$ln\ P_t(i,k) = \frac{ln\ P^{ik}}{\psi_i} - \frac{(1-\psi_i)}{\psi_i}ln\ S_{ik} - \frac{(1-\psi_i)}{\psi_i}ln\ P_{F,t} \tag{C.7}$$

Substituting this expression into the Foreign price index equation and rearranging terms delivers

$$ln\ P_{F,t} = \left(1 + \int\int_0^1 \frac{(1-\psi_j)^2}{(1-\bar{\psi})\psi_j} dj dl\right)^{-1} \int\int_0^1 \frac{1-\psi_j}{(1-\bar{\psi})\psi_j} ln\left(\frac{P^{jl}}{S_{jl}}\right) dj \tag{C.8}$$

which implies that $ln\ P_{F,t}$ is also constant, as all the elements of the RHS of this equation are constant. In turn, (C.7) now implies that $P(i,k)$ is also constant. Thus, we have established that all prices are constant across periods.[1] Finally, we note from (C.4) and (C.5) that world exports and output must also be the same in both periods, which means that all nominal and real variables of the model are constant.

Note that in period 2 $L_2^{ik} = 1$ and that in equilibrium all firms in country (i,k) will make the same investment decision so that $A_{ik,2}(m) = A_{ik}$, where A_{ik} can be either 1 or A_L depending on whether firms incur the investment cost or not. Using (3.18) it follows that country (i,k) output is given by

$$y^{i,k} = V_{ik} \tag{C.9}$$

where $V_{ik} = e^{x_{ik}} A_{ik}$. In period 1 we have $A_{ik,1}(m) = 1$ and $L_1^{ik} = 1 - u^{ik}$ from the labor market equation. Since output is the same in both periods, $u^{ik} = 1 - A_{ik}$.

Next, combine (C.5) and (C.9) with the budget constraint to find

$$\frac{P^{ik} c^{ik}}{G_{ik}} = \frac{P(i,k) V_{ik}}{D_{ik}} \tag{C.10}$$

where $D_{ik} = 1 + \left(\frac{1-\bar{\psi}}{1-\psi_i}\right) \psi_i \phi_k \left(Q - \bar{\phi} ln\ V_{ik}\right)$. Substituting this equation into (C.6) for both (i,k) and the base country we find an expression for the exchange rate:

$$S_{ik} = \frac{D_b P(i,k) V_{ik}}{D_{ik} P(b) V_b} \tag{C.11}$$

Taking logs on this equation and substituting it into the Foreign price index formula gives

$$ln\ P_F = \int\int_0^1 \frac{1-\psi_j}{1-\bar{\psi}} \left(ln\ P(b)V_b - ln\ D_b + ln\ D_{jl} - ln\ V_{jl}\right) dj dl \tag{C.12}$$

[1] The only exception is the second period wage. Using that $P_1(i,k) = P_2(i,k)$ and equation (3.19) for both periods, we get $W_2^{ik} = A_{ik} \bar{W^{ik}}$, where $\bar{W^{ik}}$ is the nominal wage in period 1 that is predetermined.

Define

$$ln\ \bar{V} = \int\int_0^1 \frac{1-\psi_j}{1-\bar{\psi}} ln\ \left(\frac{V_{jl}}{D_{jl}}\right) djdl \tag{C.13}$$

so that the Foreign price index becomes

$$P_F = \frac{P(b)V_b}{D_b \bar{V}} \tag{C.14}$$

Substituting (C.11) and (C.14) into the consumer price index formula delivers

$$\frac{P(i,k)}{P^{ik}} = \left(\frac{\bar{V} D_{ik}}{V_{ik}}\right)^{1-\psi_i} \tag{C.15}$$

Then, if we substitute this last expression into (C.10), we can solve for country (i,k) consumption as follows

$$c^{ik} = G^{ik} \left(\frac{V_{ik}}{D_{ik}}\right)^{\psi_i} \bar{V}^{1-\psi_i} \tag{C.16}$$

We finally need to derive an expression for profits. We can substitute into the formula for real profits (3.21) $y^i = V_{ik}$ and (C.15). Rearranging, the expression for profits becomes

$$\pi^{ik} = \frac{1}{\sigma} V_{ik}^{\psi_i} \left(D_{ik}\bar{V}\right)^{1-\psi_i} \tag{C.17}$$

C.2 Incentive and borrowing conditions

If all firms in country (i,k) are investing, we must make sure that any individual firm indeed must be able and willing to invest. If no firm is investing, we must make sure that for an individual firm either profits are not enough to cover the fixed cost or investing lowers the present discounted value of its profits. To check all this, we have to look at the incentive and borrowing conditions for an individual firm. We therefore need to derive expressions for second period profits for an individual firm m. We first derive an expression for second period profits of an individual firm, then derive the incentive and borrowing conditions, and finally we establish which condition is the relevant one to look at for each of the two possible states of the economy (panic or non-panic).

Using the optimal price equation and the production function, we can rewrite second period profits as

$$\Pi_2^{ik}(m) = \frac{1}{\sigma - 1}\frac{W_2^{ik} y_2^{ik}(m)}{e^{x_{ik}} A_{ik,2}(m)}$$

To determine firm's demand $y_2^{ik}(m)$, use the market clearing condition for good m (3.25), substitute the CES demands (3.13) and rearrange terms to get

$$y_2^{ik}(m) = \left(c_{ik,2}^{ik} + \int \int_0^1 c_{ik,2}^{jl} dj dl \right) \left(\frac{P_2(i,k)}{P_2^{ik}(m)} \right)^{\sigma}$$

From (C.1) we know that the first term in brackets equals y^{ik}. In any equilibrium we have that $P(i,k) = [\sigma/(\sigma-1)] \left(W^{ik}/(e^{x_{ik}} A_{ik}) \right)$. Using again the optimal price equation, the price ratio becomes

$$\frac{P(i,k)}{P_2^{ik}(m)} = \frac{A_{ik,2}(m)}{A_{ik}}$$

Substituting this ratio and the solution for output gives

$$y_2^{ik}(m) = V_{ik} \left(\frac{A_{ik,2}(m)}{A_{ik}} \right)^{\sigma}$$

Together with the fact that $W^{ik} = ((\sigma-1)/\sigma)\, P(i,k) V_{ik}$ (just rearrange the optimal price in equilibrium) second period profits become

$$\Pi_2^{ik}(m) = \frac{1}{\sigma} P(i,k) V_{ik} \left(\frac{A_{ik,2}(m)}{A_{ik}} \right)^{\sigma-1}$$

We have that $A_{ik,2}(m) = 1$ if the firm invests and $A_{ik,2}(m) = A_L$ otherwise. Substituting the corresponding expressions into the incentive condition (3.24), together with (C.15) and rearranging, we obtain the condensed version of the incentive condition:

$$\frac{\beta \left(1 - A_L^{\sigma-1}\right)}{\sigma A_{ik}^{\sigma-1}} V_{ik}^{\psi_i} \left(D_{ik} \bar{V} \right)^{1-\psi_i} \geq \kappa \tag{C.18}$$

Using (C.17), we also can write it as:

$$\frac{\beta \left(1 - A_L^{\sigma-1}\right)}{A_{ik}^{\sigma-1}} \pi^{ik} \geq \kappa \tag{C.19}$$

whereas the condensed version of the borrowing condition is

$$\pi^{ik} \geq \kappa \tag{C.20}$$

Now suppose that country (i, k) is not in a panic state, so that $A_{ik} = 1$. Since we have that $\beta\left(1 - A_L^{\sigma-1}\right) < 1$, it follows that (C.19) is a necessary and sufficient condition to ensure that (i, k) is not in a panic. Suppose instead that country (i, k) is in a panic state, so that $A_{ik} = A_L$. This will be the case if the incentive condition (C.19) does not hold, or the borrowing condition (C.20) does not hold, or neither holds. Using Assumption 1, we have

$$A_L^{\sigma-1} \leq A_L < \sigma\kappa < \beta\left(1 - A_L^{\sigma-1}\right) \tag{C.21}$$

It follows that $\beta\left(1 - A_L^{\sigma-1}\right) > A_L^{\sigma-1}$, which in turn implies that

$$\pi^{ik} < \kappa \tag{C.22}$$

is a sufficient and necessary condition to ensure that country (i, k) is in a panic state.

C.3 Proof of Propositions

C.3.1 Proof of Proposition 6

In symmetric equilibria, all countries either panic or not, while only a fraction of countries panic in asymmetric equilibria. We first consider asymmetric equilibria. Assume that a fraction ω of countries does not panic ($V_{ik} = 1$) and a fraction $1 - \omega$ does panic ($V_{ik} = A_L$). The sufficient and necessary conditions for asymmetric equilibria for a given ω between 0 and 1 are

$$\left(\bar{V} D^{np}\right)^{1-\psi} \geq V_1 \quad \textit{and} \quad A_L^{\psi}\left(\bar{V} D^{p}\right)^{1-\psi} < \kappa\sigma \tag{C.23}$$

where $D^{np} = 1 + (1-\omega)\phi^2\psi \ln A_L$, $D^p = 1 - \omega\phi^2\psi \ln A_L$, and $\ln \bar{V} = (1-\omega)\ln A_L - (\omega \ln D^{np} + (1-\omega)\ln D^p)$. The first part of Equation (C.23) implies that if countries do not panic, the incentive condition is satisfied. The second part implies that the borrowing condition is satisfied under the panic state. Now define

$$f(\omega,\psi,\phi) = (1-\omega)(1-\psi)\left(\ln A_L + \ln\left(1+(1-\omega)\phi^2\psi\ln A_L\right) - \ln\left(1-\omega\phi^2\psi\ln A_L\right)\right)$$
$$g(\omega,\psi,\phi) = \ln A_L - \omega(1-\psi)\left(\ln A_L + \ln\left(1+(1-\omega)\phi^2\psi\ln A_L\right) - \ln\left(1-\omega\phi^2\psi\ln A_L\right)\right)$$

Equation (C.23) is equivalent to $f(\omega,\psi,\phi) \geq \ln V_1$ and $g(\omega,\psi,\phi) < \ln\kappa\sigma$. Also, we can show that

$$\frac{\partial f(\omega,\psi,\phi)}{\partial\omega} \geq 0; \quad \frac{\partial f(\omega,\psi,\phi)}{\partial\psi} \geq 0; \quad \textit{and} \quad \frac{\partial f(\omega,\psi,\phi)}{\partial\phi} \leq 0$$
$$\frac{\partial g(\omega,\psi,\phi)}{\partial\omega} \geq 0; \quad \frac{\partial g(\omega,\psi,\phi)}{\partial\psi} \leq 0; \quad \textit{and} \quad \frac{\partial f(\omega,\psi,\phi)}{\partial\phi} \geq 0$$

Because $f(0,\psi,\phi) = (1-\psi)(\ln A_L + \ln(1+\phi^2\psi\ln A_L))$ with $f(0,0,\phi) = \ln A_L$ and $f(0,1,\phi) = 0$, and $\frac{\partial f(0,\psi,\phi)}{\partial\psi} > 0$, there exists a $\hat{\psi}_1 \in (0,1)$ such that $f\left(0,\hat{\psi}_1,\phi\right) = \ln V_1$, such that (i) for each $\psi > \hat{\psi}_1$, $f(0,\psi,\phi) > \ln V_1$ and (ii) for each $\psi < \hat{\psi}_1$, $f(0,\psi,\phi) < \ln V_1$.

Because $f(1,\psi,\phi) = 0$ and $\frac{\partial f(\omega,\psi,\phi)}{\partial\omega} \geq 0$, (i) implies that if $\psi > \hat{\psi}_1$, $f(\omega,\psi,\phi) > \ln V_1$ for all ω. (ii) implies if $\psi < \hat{\psi}_1$, there exists a $\hat{\omega}_1 \in (0,1)$, where $f(\hat{\omega}_1,\psi,\phi) = \ln V_1$, such that for $\omega < \hat{\omega}_1$, $f(\omega,\psi,\phi) < \ln V_1$, while for $\omega > \hat{\omega}_1$, $f(\omega,\psi,\phi) > \ln V_1$.

Analogously, because $g(1,\psi,\phi) = \psi\ln A_L + (1-\psi)\ln(1-\phi^2\psi\ln A_L)$ with $g(1,0,\phi) = 0$ and $g(1,1,\phi) = \ln A_L$, and $\frac{\partial g(1,\psi,\phi)}{\partial\psi} < 0$, there exists a $\hat{\psi}_2 \in (0,1)$, where $g\left(1,\hat{\psi}_2,\phi\right) = \ln\kappa\sigma$, such that (i) for each $\psi > \hat{\psi}_2$, $g(1,\psi,\phi) < \ln\kappa\sigma$ and (ii) for each $\psi < \hat{\psi}_2$, $g(1,\psi,\phi) > \ln\kappa\sigma$. Because $g(0,\psi,\phi) = \ln A_L < \ln\kappa\sigma$ and $\frac{\partial g(\omega,\psi,\phi)}{\partial\omega} \geq 0$, (i) implies that if $\psi > \hat{\psi}_2$, $g(\omega,\psi,\phi) < \ln\kappa\sigma$ for all ω. (ii) implies that if $\psi < \hat{\psi}_2$, there exists a $\hat{\omega}_2 \in (0,1)$, where $g(\hat{\omega}_2,\psi,\phi) = \ln\kappa\sigma$, such that for $\omega < \hat{\omega}_2$, $g(\omega,\psi,\phi) < \ln\kappa\sigma$ and for $\omega > \hat{\omega}_2$, $g(\omega,\psi,\phi) > \ln\kappa\sigma$.

Consider $\psi \leq \hat{\psi}_2$. Define $\hat{\omega}_2 = \hat{\omega}_2(\psi,\phi)$ solving $g(\hat{\omega}_2(\psi,\phi),\psi,\phi) = \ln\kappa\sigma$. It is clear that $\frac{\partial\hat{\omega}_2(\psi,\phi)}{\partial\psi} > 0$ with $\hat{\omega}_2(0,\phi) = 1 - \frac{\ln\kappa\sigma}{\ln A_L}$ and $\hat{\omega}_2\left(\hat{\psi}_2,\phi\right) = 1$. The definition of f implies $f(\hat{\omega}_2(\psi,\phi),\psi,\phi) = \left(\frac{1}{\hat{\omega}_2(\psi,\phi)} - 1\right)(\ln A_L - \ln\kappa\sigma)$. Then $\frac{\partial f(\hat{\omega}_2(\psi,\phi),\psi,\phi)}{\partial\psi} > 0$ with $f(\hat{\omega}_2(0,\phi),0,\phi) = \ln A_L$ and $f\left(\hat{\omega}_2(\hat{\psi}_2,\phi),\hat{\psi}_2,\phi\right) = 0$. Thus there exists a $\tilde{\psi} \in \left(0,\hat{\psi}_2\right)$, where $f\left(\hat{\omega}_2(\tilde{\psi},\phi),\tilde{\psi},\phi\right) = \ln V_1$, such that for $\forall\ \psi \in \left[0,\tilde{\psi}\right)$, $f(\hat{\omega}_2(\psi,\phi),\psi,\phi) < \ln V_1$, while for $\forall\ \psi \in \left[\tilde{\psi},\hat{\psi}_2\right]$, $f(\hat{\omega}_2(\psi,\phi),\psi,\phi) \geq \ln V_1$. Because $f\left(0,\tilde{\psi},\phi\right) < \ln V_1$, then $\tilde{\psi} < \hat{\psi}_1$.

Define

$$h(\psi,\phi)=\begin{cases}\ln V_1-f\left(\hat{\omega}_2(\psi,\phi),\psi,\phi\right) & if \quad (\psi,\phi)\in\left\{(\psi,\phi):\psi\le\hat{\psi}_2(\phi)\right\}\\ z(\psi,\phi) & if \quad (\psi,\phi)\in\left\{(\psi,\phi):\psi>\hat{\psi}_2(\phi)\right\}\end{cases}\tag{C.24}$$

where $z(\psi,\phi)$ can be any function that is decreasing in ψ and increasing in ϕ and $z(\hat{\psi}_2(\phi),\phi)=\ln(V_1)$. For all $(\psi,\phi)\in\left\{(\psi,\phi):\psi\le\hat{\psi}_2(\phi)\right\}$, $\frac{\partial h(\psi,\phi)}{\partial\psi}=-\frac{\partial f(\hat{\omega}_2(\psi,\phi),\psi,\phi)}{\partial\psi}<0$ and $\frac{\partial h(\psi,\phi)}{\partial\phi}=-\frac{\partial f(\hat{\omega}_2(\psi,\phi),\psi,\phi)}{\partial\phi}>0$. Therefore, for $\forall\ (\psi,\phi)\in\left\{(\psi,\phi):\psi\le\tilde{\psi}(\phi)\right\}$, $h(\psi,\phi)\ge h\left(\tilde{\psi},\phi\right)=0$. In this case, $\forall\ \omega<\hat{\omega}_2(\psi,\phi)$, $f(\omega,\psi,\phi)<\ln V_1$, and $\forall\ \omega\ge\hat{\omega}_2(\psi,\phi)$, $g(\omega,\psi,\phi)\ge\ln\kappa\sigma$. This means that there is no ω satisfying condition (C.23). Therefore there only exist symmetric equilibria when $\psi\le\tilde{\psi}(\phi)$ or, equivalently, $h(\psi,\phi)\ge 0$.

On the other hand, $\forall\ (\psi,\phi)\in\left\{(\psi,\phi):\psi>\tilde{\psi}(\phi)\right\}$, $h(\psi,\phi)<0$. For $(\psi,\phi)\in\left\{(\psi,\phi):\tilde{\psi}(\phi)<\psi\le\hat{\psi}_2(\phi)\right\}$ there exist some $\omega<\hat{\omega}_2(\psi,\phi)$ such that $f(\omega,\psi,\phi)>\ln V_1$, and $g(\omega,\psi,\phi)<\ln\kappa\sigma$. Furthermore, for $\forall\ (\psi,\phi)\in\left\{(\psi,\phi):\psi>\hat{\psi}_2(\phi)\right\}$, because $g(\omega,\psi,\phi)<\ln\kappa\sigma$ for all ω, there must exist some ω such that $f(\omega,\psi,\phi)>\ln V_1$, regardless of whether $\hat{\psi}_2>\hat{\psi}_1$ or $\hat{\psi}_2\le\hat{\psi}_1$. Thus in the case where $h(\psi,\phi)<0$, there always exist some ω such that condition (C.23) is satisfied. This means that there exist asymmetric equilibria.

C.3.2 Proof of Proposition 7

Assume

$$\sigma<\bar{\sigma}=1+\frac{\ln\left(1-\frac{1}{\beta}A_L^{\frac{2}{3}\left(1-\frac{\sqrt{3}}{3}\right)}\right)}{\ln A_L}\tag{C.25}$$

It is trivial to show that $\bar{\sigma}>2$ on $A_L\in\left(\frac{1}{e},1\right)$. We already know from the discussion in the text that when equilibria exist, they can only be of the two types in Proposition 2. We therefore need to focus on the existence of such equilibria. Profits as a function of ψ_i and $\bar{V}$, defined in Equation (30) in the main paper. Also, firms need to satisfy the incentive compatible constraint as in Equation (36) in the main paper.

First consider the first part of the proposition. The sufficient conditions for equilibria of this type to exist are

1. $\beta\left(1-A_L^{\sigma-1}\right)\bar{V}\ge\kappa\sigma$, i.e. $\bar{V}>V_1$;

2. $\bar{V}$ is at least as large as it would be when only countries in the interval $\left[0,\tilde{\psi}_1(\bar{V})\right]$ do

not panic.

The second condition says that

$$\bar{V} \geq \exp\left\{\int_{\tilde{\psi}_1}^{1} \frac{1-\psi_i}{1-\bar{\psi}} d\psi_i \ln A_L\right\} = A_L^{(1-\tilde{\psi}_1)^2} \tag{C.26}$$

where $\tilde{\psi}_1 = \frac{\ln \bar{V} - \ln \kappa\sigma}{\ln \bar{V} - \ln A_L}$. Substituting this expression for $\tilde{\psi}_1$ into (C.26) yields

$$\left(\ln \bar{V} - \ln A_L\right)^2 \ln \bar{V} \geq \left(\ln k\sigma - \ln A_L\right)^2 \ln A_L \tag{C.27}$$

Let $f(\bar{V}) = \left(\ln \bar{V} - \ln A_L\right)^2 \ln \bar{V}$. Then

$$\frac{\partial f(\bar{V})}{\partial \bar{V}} = \frac{\left(\ln \bar{V} - \ln A_L\right)\left(3\ln \bar{V} - \ln A_L\right)}{\bar{V}} \quad \begin{cases} > 0 & if \quad 3\ln \bar{V} > \ln A_L \\ < 0 & if \quad 3\ln \bar{V} < \ln A_L \end{cases}$$

Note that $f(1) = f(A_L) = 0$ and $f(\bar{V})$ reaches its local minimum at $\bar{V} = A_L^{\frac{1}{3}}$. To check whether (C.27) holds, there are two cases we need to consider:

Case 1: Choose $A_L^{1-\frac{2\sqrt{3}}{9}} \leq \kappa\sigma$. This means $f\left(A_L^{\frac{1}{3}}\right) \geq \left(\ln k\sigma - \ln A_L\right)^2 \ln A_L$. Because $f\left(A_L^{\frac{1}{3}}\right)$ is local minimum, (C.27) is always satisfied. Because of requirement of the first condition, it therefore follows that there is an equilibrium for all $\bar{V} \in [V_1, 1]$. In this case, $\bar{V}_1 = V_1$.

Case 2: Choose $\beta\left(1 - A_L^{\sigma-1}\right) A_L^{\frac{1}{3}} \leq \kappa\sigma < A_L^{1-\frac{2\sqrt{3}}{9}}$. This means $f\left(A_L^{\frac{1}{3}}\right) < \left(\ln k\sigma - \ln A_L\right)^2 \ln A_L$ and $V_1 > A_L^{\frac{1}{3}}$. Because $f\left(\bar{V}\right)$ is increasing on $\left(A_L^{\frac{1}{3}}, 1\right]$ and $f(1) = 0 > \left(\ln k\sigma - \ln A_L\right)^2 \ln A_L$, thus there exists $\tilde{V}_1 \in \left(A_L^{\frac{1}{3}}, 1\right]$, where $f\left(\tilde{V}_1\right) = \left(\ln k\sigma - \ln A_L\right)^2 \ln A_L$, such that for $\forall\ \bar{V} \in \left(\tilde{V}_1, 1\right]$, (C.27) is always satisfied. Combining with the first sufficient condition, we have $\bar{V}_1 = \max\left\{\tilde{V}_1, V_1\right\}$.

Case 3: Choose $\kappa\sigma < \beta\left(1 - A_L^{\sigma-1}\right) A_L^{\frac{1}{3}}$. This means $V_1 < A_L^{\frac{1}{3}}$. Combining the choice of $\kappa\sigma$ with Assumption (C.25), we have $\ln \kappa\sigma - \ln A_L < \ln \beta\left(1 - A_L^{\sigma-1}\right) - \frac{2}{3}\ln A_L \leq -\frac{1+\sqrt{3}}{2}\ln \beta\left(1 - A_L^{\sigma-1}\right)$. Then there exists $b \in \left(0, \frac{1+\sqrt{3}}{2}\right)$ such that $\ln \kappa\sigma - \ln A_L = -b\ln \beta\left(1 - A_L^{\sigma-1}\right)$.

In this case,

$$\begin{aligned}
& f\left(V_1\right)-\left(\ln k\sigma-\ln A_L\right)^2 \ln A_L \\
= \quad & (b+1)^2\left(\ln \beta\left(1-A_L^{\sigma-1}\right)\right)^2 \ln V_1-b^2\left(\ln \beta\left(1-A_L^{\sigma-1}\right)\right)^2 \ln A_L \\
= \quad & b^2\left(\ln \beta\left(1-A_L^{\sigma-1}\right)\right)^2\left(\left(1+\frac{1}{b}\right)^2 \ln V_1-\ln A_L\right)<0
\end{aligned}$$

where the inequality holds because $\left(1+\frac{1}{b}\right)^2 \ln V_1 < 3\ln V_1 < \ln A_L$. Also, the first sufficient condition implies $\bar{V} \in (V_1, 1]$. Thus there exists $\tilde{V}_1 \in (V_1, 1]$, where $f\left(\tilde{V}_1\right) = \left(\ln k\sigma - \ln A_L\right)^2 \ln A_L$, such that for $\forall\ \bar{V} \in \left(\tilde{V}_1, 1\right]$, (C.27) is satisfied as well. In this case, $\bar{V}_1 = \tilde{V}_1$.

In all three cases, since all countries in the region $[0, \tilde{\psi}_1]$ do not panic, it follows that for all $\bar{V} \in \left[\tilde{V}_1, 1\right]$ at least a subset of the remaining less integrated countries must panic. For the second part of proposition, the sufficient conditions for equilibria are

1. $\frac{\bar{V}}{\sigma} < \kappa$, i.e. $\bar{V} < \kappa\sigma$;
2. $\bar{V}$ is at most as large as it would be when only countries in the interval $\left[0, \tilde{\psi}_2(\bar{V})\right]$ panic.

The second condition implies that

$$\bar{V} \leq \exp\left\{\int_0^{\tilde{\psi}_2} \frac{1-\psi_i}{1-\bar{\psi}} d\psi_i \ln A_L\right\} = A_L^{\tilde{\psi}_2(2-\tilde{\psi}_2)} \tag{C.28}$$

where $\tilde{\psi}_2 = 1 - \frac{\ln V_1}{\ln \bar{V}}$. Substituting the value for $\tilde{\psi}_2$ into (C.28), we have

$$\left(\ln \bar{V}\right)^2 \ln A_L - \left(\ln \bar{V}\right)^3 \geq \left(\ln V_1\right)^2 \ln A_L \tag{C.29}$$

Let $g(\bar{V}) = \left(\ln \bar{V}\right)^2 \ln A_L - \left(\ln \bar{V}\right)^3$. Then

$$\frac{\partial g(\bar{V})}{\partial \bar{V}} = \frac{\ln \bar{V}\left(2\ln A_L - 3\ln \bar{V}\right)}{\bar{V}} \quad \begin{cases} >0 & if \quad 2\ln A_L < 3\ln \bar{V} \\ <0 & if \quad 2\ln A_L > 3\ln \bar{V} \end{cases}$$

We have $g(1) = g(A_L) = 0$ and $g(\bar{V})$ reaches its local minimum at $\bar{V} = A_L^{\frac{2}{3}}$. To check whether (C.29) holds, there are two cases we need to consider:

Case 1: Choose $\kappa\sigma \leq \beta\left(1 - A_L^{\sigma-1}\right) A_L^{\frac{2\sqrt{3}}{9}}$. This means $g\left(A_L^{\frac{2}{3}}\right) \geq (\ln V_1)^2 \ln A_L$. Because $g\left(A_L^{\frac{2}{3}}\right)$ is a local minimum, (C.29) holds for all $\bar{V}$. Because of requirement of the first condition, it therefore follows that there is an equilibrium for all $\bar{V} \in [A_L, \kappa\sigma)$. In this case, $\bar{V}_2 = \kappa\sigma$.

Case 2: Choose $\beta\left(1 - A_L^{\sigma-1}\right) A_L^{\frac{2\sqrt{3}}{9}} < \kappa\sigma \leq A_L^{\frac{2}{3}}$. This means $g\left(A_L^{\frac{2}{3}}\right) < (\ln V_1)^2 \ln A_L$. Because $g\left(\bar{V}\right)$ is decreasing on $\left[A_L, A_L^{\frac{2}{3}}\right)$ and $g\left(A_L\right) = 0 > (\ln V_1)^2 \ln A_L$, thus there exists $\tilde{V}_2 \in \left[A_L, A_L^{\frac{2}{3}}\right)$ where $g\left(\tilde{V}_2\right) = (\ln V_1)^2 \ln A_L$ such that for $\forall\, \bar{V} \in \left[A_L, \tilde{V}_2\right]$, (C.29) is always satisfied. Combining with the first sufficient condition, we have $\bar{V}_2 = \min\left\{\kappa\sigma, \tilde{V}_2\right\}$.

Case 3: Choose $A_L^{\frac{2}{3}} < \kappa\sigma$. Combining the choice of $\kappa\sigma$ with the Assumption (C.25), we have $-\ln\left(\beta\left(1 - A_L^{\sigma-1}\right)\right) > -\frac{2}{3}\left(1 - \frac{\sqrt{3}}{3}\right)\ln A_L > -\left(1 - \frac{\sqrt{3}}{3}\right)\ln\kappa\sigma$, i.e. $-\ln\kappa\sigma > -\sqrt{3}\ln V_1$. In this case,

$$g\left(\kappa\sigma\right) - (\ln V_1)^2 \ln A_L = \left(\frac{1}{3}\left(\ln\kappa\sigma\right)^2 - \left(\ln V_1\right)^2\right)\ln A_L + \left(\ln\kappa\sigma\right)^2\left(\frac{2}{3}\ln A_L - \ln\kappa\sigma\right) < 0$$

The first sufficient condition implies $\bar{V} < \kappa\sigma$. Thus there exists $\tilde{V}_2 \in [A_L, \kappa\sigma)$ where $g\left(\tilde{V}_2\right) = (\ln V_1)^2 \ln A_L$ such that for $\forall\, \bar{V} \in \left[A_L, \tilde{V}_2\right]$, (C.29) is satisfied as well. In this case, $\bar{V}_2 = \tilde{V}_2$.

In all three cases, since all countries in the region $[0, \tilde{\psi}_2]$ panic, it follows that for all $\bar{V} \in \left[A_L, \tilde{V}_2\right]$, or $\bar{V} \in \left[A_L, \tilde{V}_2\right)$, at most a subset of the remaining less integrated countries will panic.

C.3.3 Proof of Proposition 8

We first show that when the common trade integration parameter is not too large and too small, there is an equilibrium where $\left(\bar{V}, Q\right) = \left(\bar{V}^*, Q^*\right)$, such that all countries in the interval $\left[\tilde{\phi}^*, 1\right]$ panic and none of the remaining countries panic. Next, we show that for each $\left(\bar{V}, Q\right) < \left(\bar{V}^*, Q^*\right)$, there exist a continuum of equilibria such that $\left(\tilde{\phi}\left(\bar{V}, Q\right), 1\right]$ panic, with $\tilde{\phi}(\bar{V}, Q) < \tilde{\phi}^*$, and a fraction of the countries on the interval $\left[0, \tilde{\phi}\left(\bar{V}, Q\right)\right]$ panic as well.

The first type of equilibrium implies that

$$A_L^{\psi}\left(\bar{V}D_1^{p}\right)^{1-\psi}<\kappa\sigma \tag{C.30}$$

and

$$\ln\bar{V}=\left(1-\tilde{\phi}\right)\ln A_L-\left(\int_0^{\tilde{\phi}}\ln D_k^{np}dk+\int_{\tilde{\phi}}^1\ln D_k^{p}dk\right) \tag{C.31}$$

where

$$\left(\bar{V}D_{\tilde{\phi}}^{np}\right)^{1-\psi}=V_1 \tag{C.32}$$

$$D_k^{np}=1+\frac{\psi}{2}k\left(1-\tilde{\phi}^2\right)\ln A_L,\quad \mathit{and}\quad D_k^{p}=1-\frac{\psi}{2}k\tilde{\phi}^2\ln A_L \tag{C.33}$$

$$Q=\frac{1}{2}\left(1-\tilde{\phi}^2\right)\ln A_L \tag{C.34}$$

(C.30) says that the most integrated country ($k=1$) must panic. (C.31) says $\bar{V}$ must be equal to the value when all countries on the interval $(\tilde{\phi},1)$ panic and none of the others panic. (C.32) says that the country with $k=\tilde{\phi}$ is the first one (starting from the most integrated) for which there exists a no-panic equilibrium. Equation (C.33) is derived from (33) in the main paper. Substituting (C.32) and (C.33) into (C.31) yields

$$\begin{aligned}0 \;=\;& \left(\tilde{\phi}+\frac{1}{\frac{\psi}{2}\left(1-\tilde{\phi}^2\right)\ln A_L}\right)\ln\left(1+\frac{\psi}{2}\tilde{\phi}\left(1-\tilde{\phi}^2\right)\ln A_L\right)+\left(1-\frac{1}{\frac{\psi}{2}\tilde{\phi}^2\ln A_L}\right)\ln\left(1-\frac{\psi}{2}\tilde{\phi}^2\ln A_L\right)\\ -\;& \left(\tilde{\phi}-\frac{1}{\frac{\psi}{2}\tilde{\phi}^2\ln A_L}\right)\ln\left(1-\frac{\psi}{2}\tilde{\phi}^3\ln A_L\right)-1-\ln\left(1+\frac{\psi}{2}\tilde{\phi}\left(1-\tilde{\phi}^2\right)\ln A_L\right)+\frac{\ln V_1}{1-\psi}-\left(1-\tilde{\phi}\right)\ln A_L\end{aligned} \tag{C.35}$$

Define $f\left(\tilde{\phi},\phi\right)$ equal to the right hand side of (C.35). It is tedious to show that

$$\frac{\partial f\left(\tilde{\phi},\psi\right)}{\partial\tilde{\phi}}\leq 0,\quad \mathit{and}\quad \frac{\partial f\left(\tilde{\phi},\psi\right)}{\partial\psi}\leq 0$$

with $f(0,\psi)=\frac{\ln V_1}{1-\psi}-\ln A_L$ and $f(1,\psi)=\frac{\ln V_1}{1-\psi}<0$. Because $\frac{\partial f(0,\psi)}{\partial\psi}<0$ with $f(0,0)>0$ and $f(0,1)<0$, then there exist $\bar{\bar{\psi}}\in(0,1)$, where $f\left(0,\bar{\bar{\psi}}\right)=0$, i.e. $\bar{\bar{\psi}}=1-\frac{\ln V_1}{\ln A_L}$, such that for $\psi>\bar{\bar{\psi}}$, $f(0,\psi)<0$, and for $\psi<\bar{\bar{\psi}}$, $f(0,\psi)>0$. Now we only consider the case where $\psi < \bar{\bar{\psi}}$. Because $\frac{\partial f\left(\tilde{\phi},\psi\right)}{\partial\tilde{\phi}} \leq 0$ with $f\left(1,\psi\right) = \frac{\ln V_1}{1-\psi} < 0$, there exists $\tilde{\phi}^* \in (0,1)$ such that $f\left(\tilde{\phi}^*,\psi\right) = 0$. Now we have

$$\ln\bar{V}^* = \left(1-\tilde{\phi}^*\right)\ln A_L - \left(\int_0^{\tilde{\phi}^*}\ln D_k^{np}dk + \int_{\tilde{\phi}^*}^1 \ln D_k^p dk\right) \tag{C.36}$$

$$Q^* = \frac{1}{2}\left(1-\tilde{\phi}^{*2}\right)\ln A_L \tag{C.37}$$

because we have $\psi < \bar{\bar{\psi}}$ then we have $\tilde{\phi}^* > 0$. Thus we have $\bar{V}^* > A_L$ and $Q^* > \bar{\phi}\ln A_L$. In order for this equilibrium to exist, countries cannot be too trade integrated. For each $\psi \in \left(0,\bar{\bar{\psi}}\right)$, we can use (C.32) to write

$$A_L^{\psi}\left(\bar{V}^*D_1^p\right)^{1-\psi} = \frac{A_L^{\psi}}{\beta\left(1-A_L^{\sigma-1}\right)}\left(\frac{1-\frac{\psi}{2}\tilde{\phi}^{*2}\ln A_L}{1+\frac{\psi}{2}\tilde{\phi}^*\left(1-\tilde{\phi}^{*2}\right)\ln A_L}\right)^{1-\psi}\kappa\sigma \tag{C.38}$$

Define

$$g\left(\tilde{\phi}^*(\psi),\psi\right) = \psi\ln A_L - \ln\left(\beta\left(1-A_L^{\sigma-1}\right)\right) + (1-\psi)\left(\ln\left(1-\frac{\psi}{2}\left(\tilde{\phi}^*(\psi)\right)^2\ln A_L\right) - \ln\left(1+\frac{\psi}{2}\tilde{\phi}^*(\psi)\left(1-\left(\tilde{\phi}^*(\psi)\right)^2\right)\ln A_L\right)\right)$$

It is tedious to show that $\frac{\partial g\left(\tilde{\phi}^*(\psi),\psi\right)}{\partial\psi} \leq 0$. Because $g\left(\tilde{\phi}^*(0),0\right) > 0$ and $g\left(\tilde{\phi}^*(\bar{\bar{\psi}}),\bar{\bar{\psi}}\right) < 0$, then there exists $\underline{\psi} \in (0,\bar{\bar{\psi}})$, where $g\left(\tilde{\phi}^*(\underline{\psi}),\underline{\psi}\right) = 0$, such that for $\forall\ \psi \in \left(\underline{\psi},\bar{\bar{\psi}}\right)$, $g\left(\tilde{\phi}^*(\psi),\psi\right) < 0$. It implies that $A_L^{\psi}\left(\bar{V}^*D_1^p\right)^{1-\psi} < \kappa\sigma$ for $\forall\ \psi \in \left(\underline{\psi},\bar{\bar{\psi}}\right)$. This is condition (C.30).

Next we consider equilibria where $\left(\bar{V},Q\right) < \left(\bar{V}^*,Q^*\right)$. In this case, we show that there exist a continuum of equilibria such that $\left(\tilde{\phi}\left(\bar{V},Q\right),1\right]$ panic and some fraction of countries on interval $\left[0,\tilde{\phi}\left(\bar{V},Q\right)\right]$ panic as well. Equation (C.32) still holds, which determines $\tilde{\phi}\left(\bar{V},Q\right)$. D^{np} and D^p become

$$D_k^{np} = 1+\psi kQ,\ \ \textit{and}\ \ D_k^p = 1+\psi k\left(Q-\frac{1}{2}\ln A_L\right) \tag{C.39}$$

We first show that all countries on $\left(\tilde{\phi}\left(\bar{V},Q\right),1\right]$ need to panic. Due to Equation (C.32), we have $D_{\tilde{\phi}}^{np} > D_{\tilde{\phi}^*}^{np}$. Combining it with that fact $Q < Q^* < 0$, then we have $\tilde{\phi} < \tilde{\phi}^*$. In this case, for each $k \in \left(\tilde{\phi}\left(\bar{V}, Q\right), 1\right]$, because D_k^{np} is decreasing in k, then

$$\left(\bar{V} D_k^{np}\right)^{1-\psi} < \left(\bar{V} D_{\tilde{\phi}}^{np}\right)^{1-\psi} = V_1 \tag{C.40}$$

This implies $\beta\left(1 - A_L^{\sigma-1}\right) \frac{\left(\bar{V} D_k^{np}\right)^{1-\psi}}{\sigma} < \kappa$; in other words, the incentive conditions for all countries on the interval $\left(\tilde{\phi}\left(\bar{V}, Q\right), 1\right]$ are violated. Then need to check the borrowing condition of these countries in panic state. Plugging Equation (C.32) into profit function under panic state, we have

$$\begin{aligned}
& \frac{A_L^{\psi}}{\sigma}\left(\bar{V} D_1^{p}\right)^{1-\psi} \\
= \;& \frac{A_L^{\psi}}{\beta\left(1 - A_L^{\sigma-1}\right)}\left(\frac{1+\psi\left(Q - \frac{1}{2}\ln A_L\right)}{1+\psi\tilde{\phi}Q}\right)^{1-\psi}\kappa \\
= \;& \frac{A_L^{\psi}}{\beta\left(1 - A_L^{\sigma-1}\right)}\left(\frac{1+\psi\left(Q^* - \frac{1}{2}\ln A_L\right)}{1+\psi\tilde{\phi}^* Q^*}\right)^{1-\psi}\left(\frac{1+\psi\tilde{\phi}^* Q^*}{1+\psi\tilde{\phi}Q}\right)^{1-\psi}\left(\frac{1+\psi\left(Q - \frac{1}{2}\ln A_L\right)}{1+\psi\left(Q^* - \frac{1}{2}\ln A_L\right)}\right)^{1-\psi}\kappa \\
< \;& \kappa
\end{aligned}$$

where $\frac{A_L^{\psi}}{\beta\left(1-A_L^{\sigma-1}\right)}\left(\frac{1+\psi\left(Q^*-\frac{1}{2}\ln A_L\right)}{1+\psi\tilde{\phi}^* Q^*}\right)^{1-\psi} < 1$ because of (C.38); $\frac{1+\psi\tilde{\phi}^* Q^*}{1+\psi\tilde{\phi}Q} < 1$, because $D_{\tilde{\phi}}^{np} > D_{\tilde{\phi}^*}^{np}$ and thus $\tilde{\phi}^* Q^* < \tilde{\phi}Q$; and $\frac{1+\psi\left(Q-\frac{1}{2}\ln A_L\right)}{1+\psi\left(Q^*-\frac{1}{2}\ln A_L\right)} < 1$, because $Q < Q^*$. Also, because D_k^p is increasing in k, we have

$$\frac{A_L^{\psi}}{\sigma}\left(\bar{V} D_k^{p}\right)^{1-\psi} \leq \frac{A_L^{\psi}}{\sigma}\left(\bar{V} D_1^{p}\right)^{1-\psi} < \kappa \tag{C.41}$$

Therefore, both borrowing condition and incentive condition for all countries $\left(\tilde{\phi}\left(\bar{V}, Q\right), 1\right]$ are violated. They have to panic.

Next, we show that some fraction of countries $\left[0, \tilde{\phi}\right]$ need to panic as well. Suppose all $\left[0, \tilde{\phi}\right]$ do not panic. Then by definition of function f, we have $f\left(\tilde{\phi}, \psi\right) = 0$. However, since $\tilde{\phi} < \tilde{\phi}^*$, then $f\left(\tilde{\phi}, \psi\right) > f\left(\tilde{\phi}^*, \psi\right) = 0$. This is a contradiction, and hence there must be a subset B of the countries on $\left[0, \tilde{\phi}\right]$ that panic.

C.4 Microfoundations behind the transfer function

In this Appendix we argue that the transfer function T^{ik} can be seen as the reduced form of a country's net payouts structure under a particular asset market structure. The setup is related to previous work (Mendoza and Quadrini (2010)), and aims to capture in a simple way (with only one parameter) cross-country variation in financial integration and partial risk-sharing.

Suppose that, in addition to periods 1 and 2, there is a period 0 where households can trade assets that will generate payouts in the following two periods. Households from country (i, k) can sell a^{ik}_{jl} units of the asset to country (j, l) residents, with a promised payment of each asset equal to a fraction $ln\left(\frac{g^{ik}}{g^{jl}}\right)$ of nominal world exports if $g^{ik} - g^{jl} \geq 0$ and zero otherwise. Recall that $g^{ik} = y^{ik}_1/E_0 y^{ik}_1$. The asset provides income to country (j, l) residents when (j, l) performs unexpectedly worse in terms of output, with larger payments received the higher the unexpected output difference. Equal payments happen both periods as exogenous productivity shocks are permanent and the probability of a period 1 sunspot is assumed infinitesimal from the perspective of time 0.

The asset is obviously valuable so its price will be positive in equilibrium. Also note that all countries make the same type of promise and that all of them have the same independent distribution of the shocks. Therefore the price of each of these assets is the same and we can normalize them to one.

In principle full risk-sharing is possible with these assets, but we assume a standard financial friction in the form of a commitment problem. For each pair $((i, k).(j, l))$, country (i, k) can avoid the payment by paying a penalty p of

$$p = \phi_k \phi_l E^W ln\left(\frac{g^{ik}}{g^{jl}}\right) \tag{C.42}$$

Therefore

$$a^{ik}_{jl} \leq \phi_k \phi_l \tag{C.43}$$

This puts a limit on the size of the contracts that each country pair can trade. If $\phi_k \phi_l$ is low enough the constraint will be binding, so that country (i, k) will make a payment of

$$a^{ik}_{jl} E^W ln\left(\frac{g^{ik}}{g^{jl}}\right) = \phi_k \phi_l E^W ln\left(\frac{g^{ik}}{g^{jl}}\right) \tag{C.44}$$

to country (j,l) if $g^{i,k} - g^{j,l} \geq 0$, and zero otherwise. By symmetry country (i,k) receives a payment if its income is unexpectedly low relative to that of (j,l). Putting the two together, (i,k) receives a net transfer (positive or negative) from (j,l) equal to

$$\phi_k \phi_l E^W ln\left(\frac{g^{jl}}{g^{ik}}\right) \tag{C.45}$$

Integrating over all the countries, the net transfer received by (i,k) is

$$\int\int_0^1 \phi_k \phi_l E^W ln\left(\frac{g^{jl}}{g^{ik}}\right) djdl = T^{ik} \tag{C.46}$$

which is the same transfer function we assume in the paper.

It remains to be seen under which circumstances $a_{jl}^{ik} \leq \phi_k \phi_l$ is binding. From Appendix A, the solution for consumption in normal times (the non-panic state) is given by

$$c^{ik} = G^{ik}\left(\frac{e^{x_{ik}}}{D_{ik}}\right)^{\psi_i} \bar{V}^{1-\psi_i} \tag{C.47}$$

where $\overline{V}$ is the aggregate component common to all countries. The key risk-sharing component is the ratio $G^{ik}/D_{ik}^{\psi_i}$. In order for the assets to provide risk-sharing, this ratio should move in the opposite direction of the country-specific component $e^{\psi_i x_{ik}}$: if this component increases then $G^{ik}/D_{ik}^{\psi_i}$ must decrease, and vice versa. In addition, the opposite effect of $G^{ik}/D_{ik}^{\psi_i}$ cannot more than offset the change in $e^{\psi_i x_{ik}}$ or we would not have full risk-sharing either. In the good equilibrium we find that the derivative dc^{ik}/dy^{ik} evaluated at $x_{ik} = 0$ (an approximation for shocks of small magnitude) is given by

$$\left|\frac{dc^{ik}}{dx^{ik}}\right|_{x^{ik}=0} = \psi_i - \phi_k\bar{\phi}(1+\psi_i)(1-\bar{\psi}) \tag{C.48}$$

the constraint is that this derivative must be non negative.[2] If $dc^{ik}/dx^{ik} = 0$ we have full risk-sharing, as (i,k) consumption does not depend on the country-specific component $e^{x_{ik}}$. If $\phi_k = 0$ we have the well-known result that risk-sharing depends on the level of trade integration. We will make the following risk-sharing assumption: for the most integrated

[2]To derive this result, note that $Q = 0$ by a Law of Large Numbers (see Uhlig (1996)) and that $\bar{V}$ equals 1 when $x^{jl} = 0$.

country $(1,1)$ we have that

$$\phi_1 \leq \frac{1}{\bar{\phi}} \frac{\psi_1}{(1+\psi_1)(1-\bar{\psi})} \tag{C.49}$$

Since $\frac{\psi}{1+\psi}$ is increasing in ψ, $\frac{\psi_1}{1+\psi_1}$ is the minimum this object can be, and ϕ_1 is the maximum value that ϕ_k can take. It follows that if the risk-sharing assumption is satisfied then $dc^{ik}/dx^{ik} \geq 0$ for all countries. Also, note that dc^{ik}/dx^{ik} is decreasing in the size of ϕ_k. This means that a) countries are partially insured at best, and b) the level of risk-sharing (lower dc^{ik}/dx^{ik}) increases when we relax the constraint $a^{ik}_{jl} \leq \phi_k \phi_l$ by increasing the country-specific parameter ϕ_k. More risksharing is therefore always desirable, so that the constraint $a^{ik}_{jl} \leq_l \phi_k \phi_l$ is always binding.

Finally, let us point out a nice connection between the theory and the empirics under this setup. From the discussion above, the total value of the assets bought by country (i,k) in period 0 is

$$\int \int_0^1 a^{jl}_{ik} dj dl = \int \int_0^1 \phi_k \phi_l dj dl = \bar{\phi} \phi_k \tag{C.50}$$

It follows that the total value of (external) assets is proportional to the level of financial integration, which by symmetry also equals the total value of liabilities. But the total value of external assets and liabilities is precisely the measure we use in the empirical section.

Bibliography

Daron Acemoglu and David Autor. Skills, tasks and technologies: Implications for employment and earnings. *Handbook of Labor Economics*, 4:1043–1171, 2011.

Daron Acemoglu, Vasco M. Carvalho, Asuman Ozdaglar, and Alireza Tahbaz-Salehi. The network origins of aggregate fluctuations. *Econometrica*, 80:1977–2016, 2012.

Joseph G. Altonji, Anthony A. Smith, and Ivan Vidangos. Modeling earnings dynamics. *Econometrica*, 81:1395–1454, 2013.

Boragan Aruoba, Pablo Cuba-Borda, and Frank Schorfheide. Macroeconomic dynamics near the zlb: A tale of two equilibria. *The Review of Economic Studies*, 85:87–118, 2017.

Enghin Atalay. How important are sectoral shocks? *American Economic Journal: Macroeconomics*, 9(4):254–280, 2017.

David Autor, Frank Levy, and Richard Murnane. The skill content of recent technological change: An empirical exploration. *Quarterly Journal of Economics*, 118:1279–1333, 2003.

Philippe Bacchetta and Eric van Wincoop. The great recession: A self-fulfilling global panic. *American Economic Journal: Macroeconomics*, 8:177–198, 2016.

Philippe Bacchetta, Cedric Tille, and Eric van Wincoop. Self-fulfilling risk panics. *American Economic Review*, 102:3674–3700, 2012.

David K. Backus, Patrick J. Kehoe, and Finn E. Kydland. International real business cycles. *Journal of Political Economy*, 100:745–775, 1992.

Jesper Bagger, François Fontaine, Fabien Postel-Vinay, and Jean-Marc Robin. Tenure, experience, human capital, and wages: A tractable equilibrium search model of wage dynamics. *American Economic Review*, 104:1551–1596, 2014.

Gadi Barlevy. The sullying effect of recessions. *Review of Economic Studies*, 69:65–96, 2002.

Charles L. Baum and Christopher J. Ruhm. The changing benefits of early work experience. *Sourthen Economic Journal*, 83:343–363, 2016.

Philippe Belley and Lance Lochner. The changing role of family income and ability in determining educational achievement. *Journal of Human Capital*, 1:37–89, 2007.

Jess Benhabib, Pengfei Wang, and Yi Wen. Sentiments, financial markets and macroeconomic fluctuations. *Journal of Financial Economics*, 120:420–443, 2016.

Saki Bigio and Jennifer La'O. Financial frictions in production networks. *Working Paper*, 2017.

Frederic Boissay and Reint Gropp. Payment defaults and interfirm liquidity provision. *Journal of Financial Economics*, 17:1853–1894, 2013.

Michael D. Bordo and Thomas F. Helbling. International business cycle synchronization in historical perspective. *The Manchester School*, 79:208–238, 2011.

Markus K. Brunnermeier. Deciphering the liquidity and credit crunch 2007c2008. *Journal of Economic Perspectives*, 23:77–100, 2009.

Stephen G. Cecchetti, Michael R. King, and James Yetman. Weathering the financial crisis: Policy decisions or luck? *BIS working paper*, 2013.

Gabriel Chodorow-Reich. The employment effects of credit market disruptions: Firm-level evidence from the 2008–9 financial crisis. *The Quarterly Journal of Economics*, 129(1): 1–59, 2014.

Todd E. Clark and Eric van Wincoop. Borders and business cycles. *Journal of International Economics*, 55:59–85, 2001.

Harold L. Cole and Maurice Obstfeld. Commodity trade and international risk sharing: How much do financial markets matter? *Journal of Monetary Economics*, 28:3–24, 1991.

Julen Esteban-Pretel and Junichi Fujimoto. Life-cycle labor search with stochastic match quality. *International Economic Review*, 55:575–599, 2014.

Roger Farmer. The stock market crash of 2008 caused the great recession: Theory and evidence. *Journal of Economic Dynamics and Control*, 36:693–707, 2012a.

Roger Farmer. Confidence, crashes and animal spirits. *The Economic Journal*, 122:155–172, 2012b.

Andrew Foerster, Pierre-Daniel G. Sarte, and Mark W. Watson. Sectoral versus aggregate shocks: A structural factor analysis of industrial production. *Journal of Political Economy*, 119:1–38, 2011.

Jeffrey A. Frankel and Andrew K. Rose. The endogenity of the optimum currency area criteria. *Economic Journal*, 108:1009–1025, 1998.

Internatonional Monetary Fund. Dancing together? spillovers, common shocks, and the role of financial and trade linkages. *World Economic Outlook*, 2013.

Xavier Gabaix. The granular origins of aggregate fluctuations. *Econometrica*, 79:733–772, 2011.

Prasanna Gai, Andrew Haldane, and Sujit Kapadia. Complexity, concentration and contagion. *Journal of Monetary Economics*, 58:453–470, 2011.

Emilia Garcia-Appendini and Judit Montoriol-Garriga. Firms as liquidity providers: Evidence from the 2007c2008 financial crisis. *Journal of Financial Economics*, 109:272–291, 2013.

Christina Gathmann and Uta Schönberg. How general is human capital? a task-based approach. *Journal of Labor Economics*, 28:1–49, 2010.

Iida Häkkinen. Working while enrolled in a university: Does it pay? *Labour Economics*, 13: 167–189, 2006.

Robert Hall. The importance of lifetime jobs in the u.s. economy. *American Economic Review*, 72:716–724, 1982.

Bruce Hansen. Sample splitting and threshold estimation. *Econometrica*, 68:575–603, 2000.

Jonathan Heathcote and Fabrizio Perri. Wealth and volatility. *The Review of Economic Studies*, 1:1–48, 2017.

Hideaki Hirata, Ayhan Kose, and Christopher Otrok. Regionalization versus globalization. *Global Interdependence, Decoupling and Recoupling in Frank Westermann and Yin-Wong Cheung eds.*, 2014.

Andreas Hornstein and Jack Praschnik. Intermediate inputs and sectoral comovement in the business cycle. *Journal of Monetary Economics*, 40:573–595, 1997.

Michael Horvath. Cyclicality and sectoral linkages: Aggregate fluctuations from independent sectoral shocks. *Review of Economic Dynamics*, 1:781–808, 1998.

Joseph Hotz, Lixin Colin Xu, Marta Tieda, and Avner Ahituv. Are there returns to the wages of young men from working while in school? *Review of Economics and Statistics*, 84:221–236, 2002.

Henry R. Hyatt and Erika McEntarfer. Job-to-job flows and the business cycle. *CES discussion paper*, 2012.

Jean Imbs. The first global recession in decades. *IMF Economic Review*, 58:327–354, 2010.

Victoria Ivashina and David Scharfsteinb. Bank lending during the financial crisis of 2008. *Journal of Financial Economics*, 97(3):319–338, 2010.

Tor Jacobson and Erik von Schedvin. Trade credit and the propagation of corporate failure: An empirical analysis. *Econometrica*, 2016.

Philip Jung and Moritz Kuhn. Earnings losses and labor mobility over the lifecycle. *mimeo*, 2015.

Kathleen Kahle and Rene Stulz. Access to capital, investment, and the financial crisis. *Journal of Financial Economics*, 110:280–299, 2013.

Sebnem Kalemli-Ozcan, Elias Papaioannou, and Fabrizio Perri. Global banks and crisis transmission. *Journal of International Economics*, 89:495–510, 2013.

Gueorgui Kambourov and Iourii Manovskii. Occupational specificity of human capital. *International Economic Review*, 50:63–115, 2009.

Steven B. Kamin and Laurie Pounder DeMarco. How did a domestic slump turn into a global financial crisis? *Journal of International Money and Finance*, 31:10–41, 2012.

Nobuhiro Kiyotaki and John Moore. Credit chains. *Working paper*, 1997.

Philip R. Lane and Gian Maria Milesi-Ferretti. The external wealth of nations mark ii: Revised and extended estimates of foreign assets and liabilities, 1970–2004. *Journal of international Economics*, 73:223–250, 2007.

Philip R. Lane and Gian Maria Milesi-Ferretti. The cross-country incidence of the global crisis. *IMF Economic Review*, 59:77–110, 2011.

Nan Li and Vance Martin. Real sectoral spillovers: A dynamic factor analysis of the great recession. *Working paper*, 2017.

Audrey Light. In-school work experience and the returns to schooling. *Journal of Labor Economics*, 19:65–93, 2001.

Audrey Light. Job mobility and wage growth: Evidence from the nlsy79. *Monthly Labor Review*, 128:33–39, 2005.

Jeremy Lise. On-the-job search and precautionary savings. *Review of Economic Studies*, 80: 1086–1113, 2013.

Zheng Liu and Pengfei Wang. Credit constraints and self-fulfulling business cycles. *American Economic Journal: Macroeconomics*, 6:32–69, 2014.

Lance Lochner and Alexander Monge-Naranjo. Credit constraints in education. *Annual Review of Economics*, 4:225–256, 2012.

John Long and Charles Plosser. Real business cycles. *Journal of Political Economy*, 91: 36–69, 1983.

Inessa Love, Lorenzo A Preve, and Virginia Sarria Allende. Trade credit and bank credit: Evidence from recent financial crises. *Journal of Financial Economics*, 83:453–469, 2007.

Enrique G. Mendoza and Vincenzo Quadrini. Financial globalization, financial crises and contagion. *Journal of Monetary Economics*, 57:24–39, 2010.

Guido Menzio, Irina A. Telyukova, and Ludo Visschers. Directed search over the life cycle. *Review of Economic Dynamics*, 19:38–62, 2016.

Karel Mertens and Morten O. Ravn. Fiscal policy in an expectations driven liquidity trap. *The Review of Economic Studies*, 81:1637–1667, 2014.

Atif Mian and Amir Sufi. The great recession: Lessons from microeconomic data. *American Economic Review: Papers and Proceedings*, 2:1–10, 2010.

Atif Mian, Kamalesh Rao, and Amir Sufi. Household balance sheets, consumption, and the economic slump. *Quarterly Journal of Economics*, 128:1687–1726, 2013.

Toshihiko Mukoyama. The cyclicality of job-to-job transitions and its implications for aggregate productivity. *Journal of Economic Dynamics and Control*, 39:1–17, 2014.

Ha Nguyen and Rong Qian. Demand collapse or credit crunch to firms? evidence from the world bank's financial crisis survey in eastern europe. *Journal of International Money and Financ*, 47:125–144, 2014.

Erlend Nier, Jing Yang, Tanju Yorulmazer, and Amadeo Alentorn. Fiscal policy in an expectations driven liquidity trap. *Journal of Economic Dynamics and Control*, 31:2033–2060, 2007.

Fabrizio Perri and Vincenzo Quadrini. International recessions. *American Economic Review*, 108:935–984, 2018.

Jorge-Miranda Pinto and Eric Young. Flexibility and frictions in multisector models. *working paper*, 2018.

Andrew Rose and Mark Spiegel. The causes and consequences of the 2008 crisis: International linkages and american exposure. *Pacific Economic Review*, 15:340–363, 2010.

Andrew Rose and Mark Spiegel. Cross-country causes and consequences of the crisis: An update. *European Economic Review*, 55:309–324, 2011.

Stephanie Schmitt-Grohe. Comparing four models of aggregate fluctuations due to self-fulfilling expectations. *Journal of Economic Theor*, 72:96–147, 1997.

Stephanie Schmitt-Grohe and Martin Uribe. Liquidity traps and jobless recoveries. *American Economic Journal: Macroeconomics*, 9:165–204, 2017.

John Shea. Complementarities and comovements. *Journal of Money, Credit and Banking*, 34:412–433, 2002.

Andrei Shleifer and Robert Vishny. Unstable banking. *Journal of Financial Economics*, 97: 306–318, 2010.

John B Taylor. Staggered price and wage setting in macroeconomics. *Handbook of macroeconomics*, 1:1009–10504, 1999.

Volker Tjaden and Felix Wellschmied. Quantifying the contribution of search to wage inequality. *American Economic Journal: Macroeconomics*, 6:134–161, 2014.

Robert H. Topel and Michael P. Ward. Job mobility and the careers of young men. *Quarterly Journal of Economics*, 107:439–479, 1992.

Harald Uhlig. A law of large numbers for large economies. *Economic Theory*, 8:41–50, 1996.

Harald Uhlig. International contagion through leveraged financial institutions. *American Economic Journal: Macroeconomics*, 5:152–189, 2013.

Shintaro Yamaguchi. Tasks and heterogeneous human capital. *Journal of Labor Economics*, 30:1–53, 2012.