THÈSE

En vue de l'obtention du

DOCTORAT DE L'UNIVERSITE DE TOULOUSE

Délivré par l'Université Toulouse Capitole

École doctorale : **Sciences Economiques-Toulouse School of Economics**

Présentée et soutenue par

ADLER Konrad

le 4 Juli 2019

Essays in Empirical Macroeconomics

Discipline : **Sciences Economiques**

Unité de recherche : **TSE-R (UMR CNRS 5314 – INRA 1415)**

Directeur de thèse : Monsieur Franck, PORTIER, Professeur, University College London

JURY

Rapporteurs Monsieur Martial DUPAIGNE, Professeur, Université Montpellier III
Monsieur Jean-Edouard COLLIARD, Professeur, HEC Paris

Suffragants Monsieur Patrick FEVE, Professeur, Toulouse School of Economics
Monsieur Christian HELLWIG, Professeur, Toulouse School of Economics

Essays in Empirical Macroeconomics

Toulouse School of Economics

Konrad Adler

May 28, 2019

Acknowledgments

This thesis would not have been possible without the support of a number of people:

First, I would like to thank my advisor Franck Portier for his support and motivation throughout the thesis. He helped me with valuable comments to improve my work and advice about how to navigate research-related and other challenges that came up during my PhD.

The macroeconomics group at TSE, namely Christian Hellwig, Patrick Fève, Robert Ulbricht, Martial Dupaigne and Fabrice Collard, provided crucial help for the first chapter of this thesis. I am very grateful for their comments and support. I also want to thank Tim Lee and Nicolas Werquin for their encouragement at an earlier stage. My thesis has benefited from the unique research environment that TSE provides. I would like to thank the TSE faculty, especially Sébastien Pouget.

Furthermore, I would like to thank Fabrizio Zilibotti for inviting me as a visiting student at the Economics Department of the University of Zurich. I am grateful to the research community as well as the staff at UZH for letting me participate in the academic activities even after my official visit has ended. I want to thank Ralph Ossa for his advice during the last year and Christoph Winter and Charles Gottlieb for their encouragement and comments.

Discussions during coffee breaks, lunch or dinner with fellow PhD students were very important for this thesis. I would like to thank Simon Fuchs, Konstantin Shamruk, Shekhar Tomar, Jakob Hennig, François de Soyres, Alban Moura and Alexandre Gaillard from TSE and Sebastian Doerr, Felix Fattinger, Arber Fazlija and Liu Liu from UZH for their help, comments and encouragements.

I am very grateful to my parents who supported me during my entire education and especially during the PhD.

Finally, I could not have completed this thesis without my partner, Mara Wolf, who, despite long periods of separation, has always supported me in my choice of pursuing a PhD.

A special thanks goes to our son Elio for letting me sleep every now and then and thus finish my thesis. He also had to accept my job search related absence during the last year.

Abstract English

This thesis contains three essays in empirical macroeconomics. The main focus is on firm financing.

In the first chapter, I study the impact of financial covenants on firms' behavior and in particular the impact on investment. Financial covenants are conditions present in almost all bank loan contracts. When a firm does not satisfy those conditions, which are accounting ratios such as a maximal debt to earnings ratio, the bank has the right to call back the loan. In most cases banks use covenant breaches to lower the loan size or adjust other loan terms. I document that around 80% of firms are subject to covenants and most of the covenants are based on a firm's income. For the Great Recession, I use hand-collected data on firms' credit limits to estimate the contribution of income covenants to the credit crunch. I find that about a third of credit line decreases can be plausibly attributed to income covenants.

Motivated by these facts, I incorporate an income covenant into an otherwise standard heterogeneous firms model. In a calibrated version of the model I find that income covenants reduce aggregate investment by 1.3% compared to a model without financial frictions. I document that the cost from precaution, i.e. firms borrowing and investing less because they want to avoid a covenant breach, is larger than the direct cost of lower credit supply after a covenant breach. Regressions on simulated firm-level data yield very similar effects of the direct and precautionary effects of income covenants compared to actual data.

In the second chapter, Jae-Bin Ahn, Mai Chi Dao and I, document a broad-based increase in cash holdings at the firm level during the last two decades. We build a simple model in which lower trade barriers increase firms' incentives to innovate. Because innovation is risky, firms increase their liquidity holdings when tariffs fall. We test these predictions using firm-level data from five large countries and find that expanding export opportunities and, to a lesser extent, increased import competition, raise cash holdings among incumbent firms. In support of our channel, we find this effect to be stronger among firms investing in R&D.

In the third chapter, Simon Fuchs and I look at the global movie market. We show that the revenue share of sequels and adaptations of books has increased dramatically over the last two decades. During the same period the global movie market has become geographically more diverse, i.e. the revenue generated in the US has declined. We connect these two stylized facts in a model where movie studios can release one movie to a market that consists of countries with different taste. Additionally, studios face uncertainty concerning the location of a movie in the taste space. We estimate the global taste space based on market shares. We investigate whether the change in the composition of global demand can account for the increase in the revenue share of sequels. Our current results suggest this is not the case.

Abstract French

Cette thèse contient trois essais en macroéconomie empirique. L'accent est mis sur le financement des entreprises.

Le premier chapitre étudie l'impact des clauses financières restrictives (covenants financiers) sur le comportement des entreprises et, en particulier, sur les investissements. Les covenants financiers sont des conditions présentes dans presque tous les contrats de prêt bancaire. Lorsqu'une entreprise ne remplit pas ces conditions, qui sont des ratios comptables tels qu'un ratio maximal de dette divisé par le revenu, la banque obtient le droit de rappeler le prêt. Après une violation d'un covenant, les banques réduisent souvent le montant du prêt ou modifient les conditions de prêt. Je trouve qu'environ 80% des entreprises sont soumises à des covenants et que la plupart des covenants sont basées sur le revenu d'une entreprise. Pour la crise de 2008, j'utilise des données manuellement collectées sur les limites de crédit des entreprises pour estimer la contribution des covenants de revenus à la contraction du crédit. Je trouve qu'environ un tiers des diminutions de lignes de crédit peut être attribué de manière plausible aux covenants du revenu.

Motivé par ces faits, j'intègre des covenants sur le revenu dans un modèle d'entreprises hétérogènes par ailleurs standard. Dans une version calibrée du modèle, j'ai constaté que les covenants réduisent l'investissement global de 1,3% par rapport à un modèle sans frictions financières. Je montre que le coût de précaution, c'est-à-dire les entreprises qui empruntent et investissent moins parce qu'elles veulent éviter une violation d'un covenant, est supérieur au coût direct de la réduction de l'offre de crédit après la violation du covenant. Les régressions sur des données simulées produisent des effets directs et de précaution très similaires aux données réelles.

Dans le deuxième chapitre, JaeBin Ahn, Mai Chi Dao et moi-même documentons une augmentation généralisée des actifs financiers liquides des entreprises au cours des deux dernières décennies. Nous construisons un modèle simple dans lequel une diminution des barrières commerciales incite les entreprises à innover. Parce que l'innovation est une activité à haut risque, les entreprises augmentent leurs avoirs en actif liquide lorsque les droits de douane baissent. Nous testons ces prévisions à l'aide de données de cinq économies majeures et nous constatons que l'augmentation des opportunités d'exportation et, dans une moindre mesure, la concurrence par des importations, accroissent les avoirs en actifs liquides des entreprises. À l'appui de notre interprétation, nous constatons que cet effet est plus marqué chez les entreprises qui investissent dans la recherche et le développement.

Dans le troisième chapitre, Simon Fuchs et moi examinons le marché mondial de la création cinématographique. Nous montrons que 1) la part des revenus des suites et des adaptations de livres a considérablement augmenté au cours des deux dernières décennies et, 2) que le marché mondial de la création cinématographique est devenu plus global, avec la part des revenus total générés aux États-Unis en forte diminution. Nous établissons un lien entre ces deux faits stylisés

grâce à un modèle dans lequel les studios de cinéma peuvent diffuser un film sur un marché composé de pays aux goûts différents. De plus, les studios sont confrontés à des incertitudes quant à l'emplacement d'un film dans l'espace "gustatif". Nous estimons cet espace "gustatif" global en utilisant les parts de marché des films observé. Lorsque la part de marché de l'Asie du Sud-Est sur le marché mondial du film augmente, les suites offrent une protection contre le risque accru.

Contents

List of Figures

List of Tables

Chapter 1

Financial Covenants, Firm Financing and Investment

Konrad Adler[1]

Abstract
What is the impact of financial covenants on investment? Financial covenants are conditions included in almost all loan contracts giving a bank the right to call back a loan when a borrower does not satisfy the condition. In the data, 80% of covenants are conditions on a firm's earnings. Using a new dataset on credit limits and data on covenant thresholds I show that earnings covenants can account for up to 30% of credit line decreases during the Great Recession. Motivated by these facts I incorporate earnings covenants into an Aiyagari economy with production. In the model as in the data I find that firms' investment i) falls after a covenant breach and ii) increases the further away the firm moves from the covenant threshold. Because covenant breaches are costly firms reduce their borrowing and investment when a covenant breach becomes more likely. Calibrating the model to a sample of US public firms I find that aggregate investment at steady state is 1.3% lower relative to a frictionless economy and that the direct cost from covenant breaches accounts for only 20% of the total decrease, whereas the precautionary effect accounts for 80% of the total decrease.

[1] I gratefully acknowledge the data from SDC Platinum sponsored by the Department of Banking and Finance of the University of Zurich.

1.1 Introduction

Financial covenants are conditions, set as minimal or maximal thresholds, present in almost all bank loan contracts. In case a borrower exceeds the threshold the covenant gives a bank the right to call back a loan immediately. Therefore firms pay close attention to covenants. Covenant breaches are both frequent, more than 10% of firms breach a covenant in an average year, and have a strong impact on firms' investment, employment and innovation. Below is an example from an actual loan contract:

> *The borrower shall not at any time permit the ratio (the "leverage ratio") of (i) total debt of the borrower to (ii) adjusted ebitda of the borrower to be greater than 4.00 to 1.00.*
>
> *The borrower shall not permit its consolidated net worth at anytime to be less than $70,000,000*

Starting with Bernanke and Gertler (1989) and Kiyotaki and Moore (1997) financial frictions in macroeconomics have been thought of mainly as borrowing constraints depending on a firm's net worth or collateral. The impact of collateral constraints on firm behavior has been studied extensively and is well understood. Recently, credit spreads and the interaction of risk with financial frictions have received more attention. However, the aggregate implications of financial covenants and how financial covenants affect firms' behavior have remained largely unexplored so far.

In this paper I study the impact of financial covenants on investment. I incorporate financial covenants into an otherwise standard heterogeneous firms model. When the risk of a covenant breach increases, firms in the model reduce their borrowing, and therefore also their investment. This precautionary cost on investment exists in addition to the direct cost of a reduced credit supply after a covenant breach. In a calibrated version of the model the aggregate precautionary cost of covenants in terms of investment is larger than the direct cost. Using detailed firm-level data on covenant breaches and contract terms I confirm the importance of the direct and precautionary cost of covenants on investment. Regressions using simulated model data yield coefficient estimates very close to those from regressions with actual data.

Covenants based on a firm's earnings are included in 80% of contracts, which is much more frequent than covenants on net worth.[2] I therefore focus on earnings covenants as the empirically relevant case. A covenant breach gives the bank the right to immediately call back the entire loan, but in practice this is not very common. After a covenant breach banks increase interest rates, lower the maturity of the loan, lower the credit line limit or just waive the covenant breach. To assess the quantitative importance of earnings

[2] This fact, while well known in the finance and accounting literature for a long time (Christensen and Nikolaev (2012), Demerjian (2011)), has not been considered in macroeconomics until very recently.

covenants on firms' access to credit I focus on credit line limit decreases because they directly restrict the quantity of credit available to a firm. I combine a novel dataset[3] on credit line limits during the Great Recession[4] with data on covenant thresholds. I find firms that breached an earnings covenant during the Great Recession to be almost twice as likely to experience a credit line decrease compared to firms in compliance with their covenant. Combining this finding with the earnings distribution of the full sample in a reduced form model, I find that earnings covenants can potentially account for 30% of credit cuts during the Great Recession. Because the consequences of a covenant breach can be severe, I expect firms to try to avoid getting too close to the covenant threshold. When I compare the distribution of accounting ratios used in the covenant against the covenant threshold I find that firms bunch at a "safe" distance from the threshold. This bunching suggest that firms indeed try to stay clear of the covenant threshold.

Motivated by the empirical evidence I add an earnings covenant to an Aiyagari (1994) economy with production. I use the model to obtain an estimate of the aggregate impact of earnings covenants on investment. In addition, the model is used as a laboratory to compare aggregate and firm-level outcomes when I replace the earnings covenant by a net worth covenant or a traditional collateral constraint. In the earnings covenant model firms can borrow a fraction of their capital stock. Unlike in the traditional models this fraction, the tightness of the collateral constraint, changes over time depending on whether the firm satisfies the earnings covenant or not. As long as a firms satisfies the covenant it can borrow an unlimited amount. But when a firm breaches a covenant the bank obtains the right to tighten the borrowing limit. Banks use this option to cut a firm's credit in an exogenously set fraction of cases. While simplistic, modeling the earnings covenant in this way can be interpreted as a reduced form of a more complicated model, in which covenants allocate control rights optimally when contracts are incomplete.[5]

I calibrate the earnings covenant model to the sample of US public firms and find that aggregate investment is 1.3% lower than in an economy without financial frictions. The precautionary effect of avoiding a covenant breach accounts for 80% of the cost, while the remaining 20% is the direct cost coming from a tighter collateral constraint after a covenant breach. I validate the aggregate findings by simulating the model and comparing the simulated data to actual data. At the firm-level a covenant breach, i.e. the direct cost, reduces the investment rate by 8% of the standard deviation in the data and 7% in the model generated data. I estimate the precautionary cost by regressing investment on the log distance to the covenant threshold[6]. A one standard deviation

[3] I parse SEC filings for information about firms' credit line limits.

[4] About 20% of the firms in my sample breach a covenant during the Great Recession, which makes this period particularly interesting to study. However, the same mechanism is at work during normal times.

[5] Aghion and Bolton (1992) provide conditions when a contingent control allocation between the firms insiders and outside investors is optimal. Dewatripont and Tirole (1994) study why debtholders receive control rights in bad states and equity holders in good states.

[6] Atkeson et al. (2017) propose the distance to insolvency to measure if a firm is in financial distress. Because covenants typically become binding before a firm is insolvent, taking into account the distance to the covenant

increase in the log distance to the covenant threshold increases the investment rate by 3% of the standard deviation in the data and 5% in the model generated data. Because these coefficients are not targeted by the calibration, I interpret this as a success of my model to match the data.

I compare the predictions of the earnings covenant model against a traditional model with a collateral constraint and a model with a covenant on net worth instead of earnings. The traditional model with a fixed collateral constraint does not generate the same behavior by firms as the earnings covenant model. Firms in the collateral constraint model bunch directly at the constraint. This different behavior is also mirrored in the decomposition of the total cost of the constraint in terms of investment. In the collateral constraint model the direct cost in terms of investment of firms facing a binding constraint accounts a larger part of the total cost relative to the precautionary cost. In the net worth covenant model, the share of firms breaching a covenant is much lower than in the earnings covenant model. Because net worth as a stock variable is less volatile than earnings, firms might be better able to avoid a net worth covenant breach than an earnings covenant breach. Using the simulated firm-level data from the models with net worth and earnings covenants I find evidence supporting this interpretation: firms breaching a net worth covenant are hit by a series of very bad productivity shocks before breaching the covenant, whereas firms in the earnings covenant model are hit by just one bad productivity shock.

Related literature This paper contributes to the literature studying the impact of financial frictions in macroeconomics. Drechsel (2018) investigates the effect of shocks to investment efficiency for aggregate and firm-level debt if firms are subject to earnings and collateral constraints, but does not explicitly model the constraint as a covenant, which in my model yields different results. There is a large literature on the effects of financial frictions in heterogeneous firm models. In Khan and Thomas (2013) investment is partially irreversible and firms face a collateral constraint. The combination of these two frictions amplify financial shocks which are modeled as a tightening of the collateral constraint. Buera and Moll (2015) find a tightening of a collateral constraint to be isomorphic with an increase in the efficiency wedge under the assumption of i.i.d. productivity shocks. Gopinath et al. (2017) show that a model with a size-dependent collateral constraint matches the Spanish firm data better than a simple collateral constraint. My paper differs from these articles because I model the financial friction as an earnings covenant. I show that earnings covenants impose an additional cost on firms, which is not present in models with collateral constraints, because firms try to avoid getting too close to the covenant threshold. Furthermore I find that this precautionary cost of covenants is more important than the direct cost of hitting the constraint.

threshold might improve their measure.

The second contribution is empirical. A large empirical finance literature studies the impact of covenant breaches on firm's access to credit (Sufi, 2009), employment (Falato and Liang, 2016) and investment (Chava and Roberts, 2008). But there is little evidence on the cost of avoiding a covenant breach. I provide firm-level evidence that the precautionary cost might be large.

In the empirical macroeconomics literature, Lian and Ma (2018) document that 80% of loans to large US public firms have a cash-flow-based borrowing base and that most firms are subject to earnings covenants. They investigate the implications of earnings based constraints for borrowing and investment empirically and explore how they arise in different model settings. However, Lian and Ma (2018) do not distinguish between covenants and constraints in their empirical part, whereas I find in my model that the difference between constraint and covenant matters.

Chodorow-Reich and Falato (2017) find that the decline in loan supply during the Great Recession mainly happened through covenants. They use an administrative data set to show that lenders in bad health used covenant breaches to cut back lending. Murfin (2012) finds that a bank writes tighter covenants than other banks after suffering a default in its loan portfolio, even when the default occurred in a different industry and region. Both of these articles show how shocks exogenous to a borrower's financial health affect the loan outcome after a covenant breach. This supports a causal interpretation of the results in this paper relating earnings covenant breaches to cuts in credit supply during the Great Recession.

The present paper is related to Terry (2017) who studies the aggregate growth effect from firms reducing their R&D expenditure to meet earnings targets. Financial covenants are a common reason for why firms want to meet earnings targets.Catherine et al. (2018) quantifies the cost of collateral constraints without explicitly modeling the benefit of this constraint. The benefit of covenants has been estimated at the firm-level by Green (2018) who finds the benefit of a restrictive covenant set for a bond to be 2.4% of a firm's total value. Similarly, Matvos (2013) finds that the benefit of a covenant typically exceeds the value of the interest spread paid on a loan. Neither Green (2018) nor Matvos (2013) explicitly model the precautionary reduction in borrowing and investment because of covenants.

The rest of the paper is organized as follows: Section 1.2 explains the institutional framework. Section 1.3 describes data sources and provides descriptive statistics. Section 1.4 presents the empirical results: first, I explore the relationship between earnings, net worth and access to credit during the Great Recession. Then I show how covenants affect firm-level investment. In Section 1.5 I add earnings covenants to a heterogeneous firms model and present the details of the calibration. Section 1.6 presents the aggregate and firm-level results. Section 1.7 concludes.

1.2 Institutional Framework

This section presents an example of a covenant and details the steps of how a covenant breach can lead to a reduction of a firm's access to credit.

Figure 1.1 shows a typical firm-bank relationship and a typical loan contract. The loan contract specifies the different terms of the loan: interest rate, maturity and financial covenants[7]. The firm must have a debt/earnings ratio below 4. Earnings in covenants are usually earnings before interest, taxes, depreciation and amortization (EBITDA). I will use this definition of earnings in this paper. Additionally the firm in this example contract must have a minimal amount of net worth of 70 million. Net worth in covenants is defined as the book value of assets minus the book value of liabilities. I use this accounting definition of net worth throughout the paper.

As long as the firm satisfies the covenants, the bank provides the firm with funding under a term loan and a credit line limit. The credit line limit specifies the maximal amount a firm can borrow using the credit line. A credit line, unlike a term loan, can be used and repaid several times until maturity. To maintain a credit line firms usually pay a fixed fee and variable interest depending on their usage.

Covenant Breach Now, I will discuss the steps of how a covenant breach might lead to a cut in available credit for a firm.

Step I Suppose a negative demand shock lowers the firm's earnings, i.e. because of lower sales, such that given its level of debt the debt/earnings ratio exceeds 4. *Step II* The firm reports the covenant breach to the bank. *Step III* At this stage the bank has the right to immediately call back the loan. In practice this extreme outcome rarely happens. Banks do however frequently tighten different terms of the loan. They increase interest rates, shorten the maturity or lower the credit line limit. Banks will take into account the borrower's financial health, but, as shown in the diagram, banks' reaction also depends on their own financial health[8]. *Step IV* The firm's access to credit might change depending on the bank's reaction.

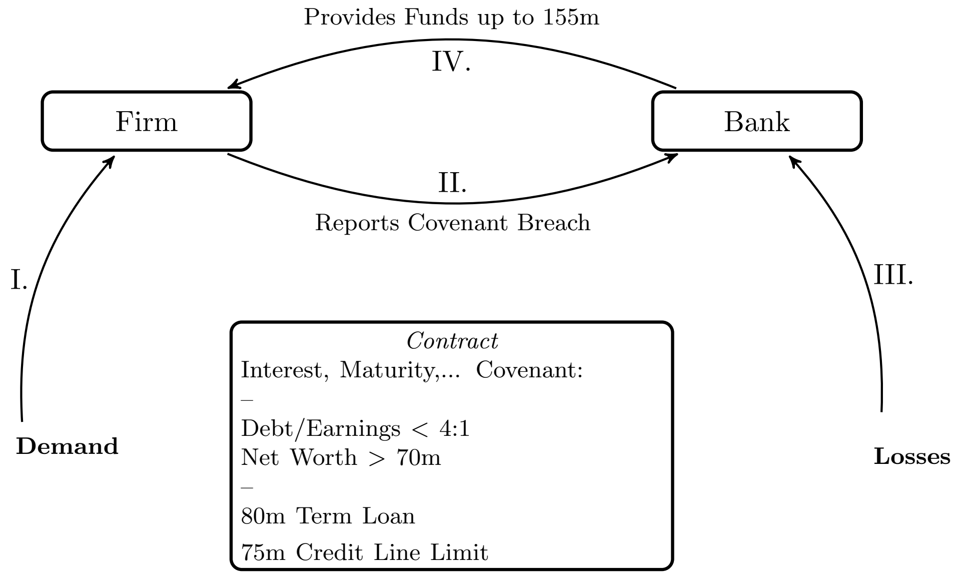
1.3 Data and Descriptives

This section describes data sources and provides descriptive statistics about the share of firms with earnings and net worth covenants

[7]In addition to *financial* covenants there exist also informational covenants and negative covenants. Informational covenants require the borrower to provide detailed financial reports to the lender. Negative covenants prohibit the borrower from selling assets, for example. In this paper I only focus on financial covenants.

[8]See Chodorow-Reich and Falato (2017) and Murfin (2012) for how factors on the bank side unrelated to a borrower's financial health affect credit supply.

Figure 1.1: Firm-Bank Relationship



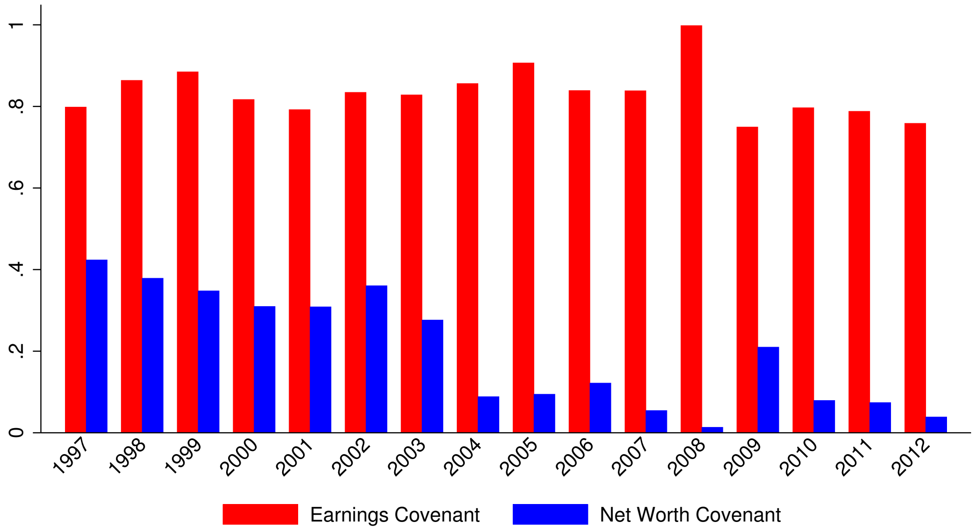
Notes: This diagram shows a firm-bank relationship and a typical contract. Steps I.-IV. detail how a covenant breach might affect a firm's access to financing.

1.3.1 Data

I use data from US public firms from 1997 until 2014. The data come from four sources: accounting data come from Standard & Poor's Compustat, loan-level data are from Thomson Reuter's DealScan, data on credit lines between 1997 and 2003 from Sufi (2009) and the hand-collected data about covenant breaches over the entire sample period and credit limits during the Great Recession directly from SEC filings. Details of the data treatment are provided in Appendix 1.8.2.

Hand-collected data I use a modified text search algorithm based on Nini et al. (2012) to extract a dummy for covenant violations for the entire SEC-Computstat sample. Where available I also collect the type of covenant the firm has breached. To obtain information about firms' credit limits during the Great Recession I extract parts of the filings related to credit lines and then verify the information manually for a sub sample of 1238 firms from 2007 until 2009. Appendix 1.8.3 provides the details of the search algorithms used for the data I collected myself. Table 1.1 shows descriptive statistics for this sample.

Figure 1.2: Fraction of New Loan Contracts and Covenant Types



Notes: Fraction of new contracts weighted by loan size containing either an earnings or a net worth covenant in a given year. Some contracts contain both, therefore the fractions do not sum up to one. The sample is limited to firms with non-missing data in both DealScan and Compustat.

1.3.2 Descriptives

Prevalence of covenants Covenants are very common: 81% of firm-years in the dataset by Sufi (2009) covering all US public firms have a credit line[9] and almost all credit line contracts contain covenants. Using dealScan data, I classify covenants into earnings and net worth covenants. The details of the classification can be found in the appendix 1.8.4. This data set includes information on covenants from more than 15,000 contracts from over 5500 different firms. Figure 1.2 shows the fraction of contracts weighted by loan size[10] containing earnings or net worth covenants over time. The fraction of earnings covenants averages around 80% over the sample period, whereas net worth covenants have become less frequent. In the rest of the paper I will therefore focus on earnings covenants as the empirically relevant case.

Covenant breaches How frequent are covenant breaches? On average about 10% of firms in my sample are breaching a covenant in a given year. Because the search algorithm I use is conservative the actual number is probably higher. This makes covenant breaches a much more frequent event than actual default.

[9] In the hand-collected data covering the Great Recession 77% of firms have a credit line

[10] See Figure 1.11 in the Appendix for the unweighted version of this graph.

1.4 Empirical evidence

This section has two parts. First, I explore the relationship between earnings, net worth and access to credit during the Great Recession. I document that earnings covenants are likely to account for a sizable share of credit line decreases during the Great Recession. In the second part, I provide evidence that covenants affect a firm's investment even when a firm is not breaching the covenant. I find that firms try to keep a "safe" distance from the covenant threshold.

1.4.1 The decrease in loans during the Great Recession

I use the hand-collected data on firm's credit limits during the Great Recession to show that a firm's earnings might be as important for access to credit as its net worth. I focus on credit limits instead of other loan terms because when a bank wants to lower its exposure to a firm lowering the credit limit is the most direct way to do so.

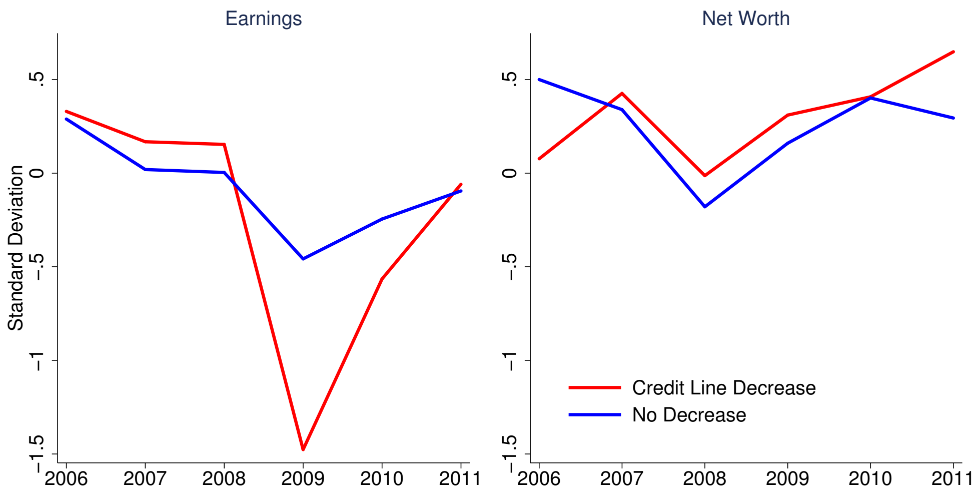
Then I use data on earnings covenant thresholds and show that most firms with a credit cut have breached their earnings covenant the year before the credit cut.

At the firm level: net worth, earnings and credit line cuts In most macroeconomic models financial frictions are modeled as a constraint on net worth or capital. Firms with falling net worth should therefore lose access to credit. In Figure 1.3 however, the median firm which had a reduction in the size of their credit line during the Great Recession experienced a large drop in earnings but only a small fall in net worth.

An explanation for the importance of earnings could be covenants, because most covenants are conditions on earnings. Firms with low earnings might breach a covenant and lose access to part of their credit line. I use the hand-collected dataset on firms' credit lines during the Great Recession to test the relation between net worth, earnings and the probability of a credit line decrease. Figure 1.4 plots the coefficients of a linear probability model[11]. In the first regression (coefficients in blue) I find that earnings have a significant impact on the probability of a credit line decrease during the Great Recession, whereas net worth does not. A one standard deviation decrease in a firm's earnings increases the probability of a credit line decrease by 1.5 percentage points. The effect is large because the unconditional probability of a credit line decrease in 4% (see Table 1.1). Then I add a dummy variable for a covenant breach (coefficients in red) and I find that a covenant breach has a significant positive impact on the probability of a credit line decrease. In the second regression earnings are not longer significant, which suggests that the impact of earnings on firms' access to credit is at least partially through earnings covenants. A covenant breach increases the probability of a credit line decrease by almost 2 percentage points.

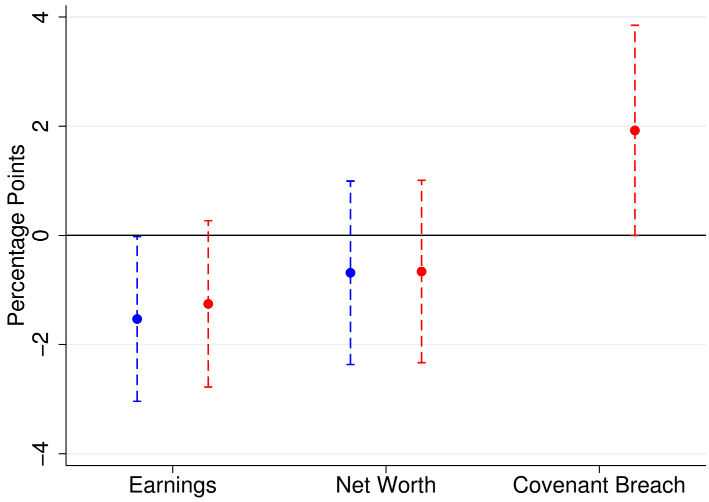
[11] I obtain similar results with a probit model, see Figure 1.13 in the Appendix.

Figure 1.3: Median Earnings and Net Worth



Notes: The graph shows median *Net worth*, which is book value of assets minus book value of liabilities and *Earnings*, which are earnings before interest, taxes, depreciation and amortization. Both net worth and earnings are divided by total assets and centered and standardized using the 2003-2006 mean and standard deviation. *Credit line decrease* equals one if the firm's credit line divided by its 2006 total assets decreases by more than 25% between 2008 and 2009.

Figure 1.4: Coefficients from a Linear Probability Model



Notes: The graph shows the coefficients from two linear probability models. *Credit line decrease* = *Earnings* + *Net Worth* (in blue) *Covenant Breach* is then added (in red). See Table 1.2 in the Appendix. *Credit line decrease* equals one if the firm's credit line divided by its 2006 assets decreases by more than 25% between 2007 and 2008 or between 2008 and 2009. Both net worth and earnings are divided by assets and centered and standardized using the 2003-2006 mean and standard deviation. Industry fixed effects are included and all variables standardized across firms.

Low earnings realizations can cause firms to breach a covenant and lower demand for credit at the same time. I use the cross-sectional variation in bank health during the Great Recession as in Chodorow-Reich and Falato (2017) to verify that the previous effects are not due to credit demand. In table 1.3 I confirm the results in Chodorow-Reich and Falato (2017). It is the combination of a covenant breach and a bank in bad financial health which makes the probability of a credit line decrease significantly more likely. This suggest that credit supply rather than credit demand has played the key role in the decision of whether to decrease a line of credit during the Great Recession or not.

In the aggregate: earnings covenants and credit line cuts How much of the relationship between access to credit and earnings can be explained by earnings covenants? To answer this question I combine the credit limit data with data on covenant thresholds. I restrict the sample to firms with only earnings covenants and firms with a maximal debt/earnings covenant. Debt/earnings covenants are the most frequent type of covenant overall and the definition used in the contracts is relatively uniform across firms. I only consider credit line decreases of more than 25% relative to the previous year. I sort firms into equally-sized earnings/assets bins and then compute the number of credit line decreases in the next year[12] for each bin.

Data on covenant thresholds are only available for subsample of firms. To obtain an estimate of the aggregate effect of earnings covenants on credit limit cuts during the Great Recession I extrapolate the results from the subsample with non-missing covenant thresholds to the full Compustat sample using a simple reduced form model. For each earnings/asset bin $\{y/a\}_i$ in the full sample I compute the number of firms with a credit line decrease likely due to an earnings covenant breach by multiplying the number of firms with the probabilities in Table 1.4. Summing over all bins I find that 2.1% of credit cuts during the Great Recession can potentially be attributed to earnings covenant breaches. Relative to the baseline probability of 7% in the hand-collected credit line sample earnings covenants could account for up to 31% of all credit line decreases.

Robustness Because the measurement error from covenant thresholds could be large, I provide additional evidence that earnings covenants matter for credit cuts. For a subset of covenant breaches firms report the type of covenant breached. In the appendix 1.8.6 I document that based on this alternative measurement most firms breached an earnings covenant during the Great Recession. Additionally it does not seem that the outcome in terms of access to credit of earnings covenant breaches is different from other types of covenants breached.

[12]The renegotiation after a covenant breach takes time.

1.4.2 The impact of covenants on investment

In this subsection I turn to the impact of earnings covenants on firm-level investment. A covenant breach gives the bank the right to cut a firm's credit. When firms cannot substitute bank credit easily, firms with a lower credit limit after a covenant breach have to reduce investment. This decrease is the direct effect of a covenant breach. The direct effect is well-known as has been estimated by Chava and Roberts (2008) for example. Covenants might however affect a firm's investment policy even without a covenant breach. Because covenant breaches are costly, firms might try to avoid getting too close to the threshold. To stay at a safe distance from the covenant threshold firms might have to reduce borrowing and investment. I call this the precautionary effect of covenants on investment. The precautionary effect of covenants has not been investigated so far.

A first indication that there is indeed a precautionary effect is the bunching of firms at a distance from the covenant threshold. I select firms subject to a debt/earnings covenant and plot the distribution of debt/earnings separately for firms with different threshold levels. For each threshold value the distributions in Figure 1.5 peak at a distance to the respective covenant threshold. This suggests that firms try to stay at a safe distance from their covenant threshold. For a given level of earnings firms can reduce the amount of debt they use to reduce the probability of a breach. This is the mechanism I focus on in this paper. Alternatively, firms can also manipulate their earnings to satisfy the earnings covenant for a given level of debt. Earnings manipulation might be an important factor for why firms are able to stay at a safe distance from the threshold in Figure 1.5. In the regressions below, however, earnings manipulation makes it more difficult to find a precautionary effect in the data.[13]

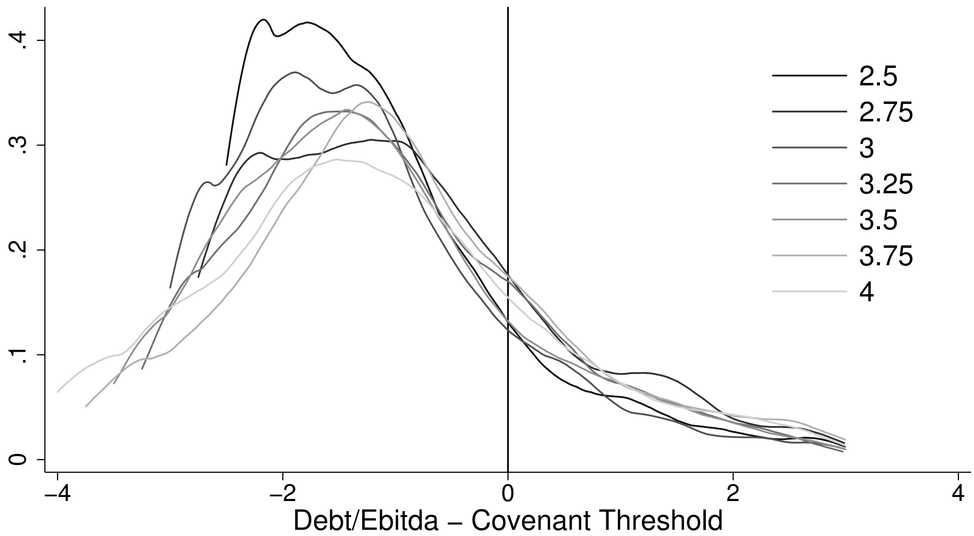
Covenant thresholds are not set randomly. Therefore it could be that firms subject to different thresholds have a different distribution of debt/earnings for other reasons than the covenant threshold. The debt/earnings distribution based on simulated model, in which the covenant threshold is exogenous, however resembles closely to the distribution observed in the data[14].

Regression I estimate the impact of a covenant breach on investment by regressing the investment on a lagged dummy for a covenant breach. The covenant breach dummy equals one when a firm breaches a covenant and has not breached a covenant the year before. The first and second columns of Table 1.6 show that a covenant breach has a significant negative effect on a firm's investment rate. A covenant breach reduces the

[13] As for other types of manipulation Graham et al. (2005) report survey evidence that managers are more likely to lower investment to avoid a covenant breach, rather than manipulating a financial report.

[14] See results in Section 1.6.2 below.

Figure 1.5: Debt/Earnings Distributions Under Different Covenant Thresholds



Notes: This graph shows the distributions of debt/earnings for firms with different debt/earnings covenant thresholds. The distributions are smoothed using a kernel density estimator. Firms to the right of the zero line breach their covenant.

investment rate by 1.2 percentage points which corresponds to 5% of the mean and 8% of the standard deviation of the investment rate.[15]

To quantify the precautionary effect on investment at the firm-level, I regress the investment rate on the log distance of a firm's debt/earnings covenant to its covenant threshold. I take the log distance instead of the simple difference because I expect the precautionary effect to increase non-linearly when a firm approaches the covenant threshold. I partition log distance to the threshold into a positive and a negative part. The negative part indicates a covenant breach as predicted by the threshold. Because the thresholds are measured with error, I also include a dummy for covenant breach based on the text-search. To exclude any impact from the *level* of debt/earnings I also include this variable. Columns three and four of Table 1.6 show that an increase in the log distance to the covenant threshold has a significant positive impact on the investment rate. A one standard deviation increase in the distance to the covenant threshold increases investment by 0.87*0.52 which corresponds to 2% of the mean and 3% of the standard deviation of the investment rate.

At which distance to the threshold do firms start reducing investment? To find out I sort firm-years into different bins depending on the distance to the threshold. Then I run a regression with investment/capital as a dependent variable and dummies for each bins as independent variables. Figure 1.12 suggests that firms start reducing investment when the

[15] Using quarterly data Chava and Roberts (2008) find that a covenant breach reduces the investment rate by 1.5 percentage points.

distance to the covenant threshold falls below one standard deviation of debt/earnings. Firms which are only 0.25 standard deviation away from the threshold reduce investment the most. The dummy variables for distances above one standard deviation from the threshold are not significant, i.e. firms' investment is not significantly different from those firms that are three or more standard deviations away, which provide the reference group in the regression.

Table 1.7 shows that the coefficient on the distance to the covenant threshold is robust to excluding contracts containing explicit limitations on capital expenditures and the inclusion of industry-year fixed effects in addition to the firm fixed effects. The impact is similar for next year's investment and also when I replace the measure of the distance to the covenant by the distance divided by the firm-specific standard deviation of debt/earnings.

In Table 1.8 I find that the distance to the covenant threshold has a significant effects on the probability of a firm paying its shareholders dividends as well as on a firm's net debt issuance and cash holdings.

1.5 Quantitative Model

In this section, I add an earnings covenant to an otherwise standard dynamic heterogeneous firms model with financial frictions. Consider a small open economy with a large number of competitive entrepreneurs[16] and banks. Entrepreneurs are subject to a collateral constraint which the bank can tighten whenever a firm exceeds the earnings covenant threshold.

1.5.1 The entrepreneur's problem

Entrepreneurs have access to a decreasing returns to scale production function which takes capital as its only input, i.e. $y_{it} = z_{it}k_{it}^{\alpha}$ with z_{it} a persistent firm-specific productivity shock and k_{it} the capital stock the firm owns. Entrepreneurs can save and borrow using uncontingent one period debt b which yields the exogenous interest rate r.

As in most of the literature, entrepreneurs in this model keep borrowing because every year a fraction γ of firms is forced to consume all their assets and is re-born the next period with a low stock of capital and savings. In a model without financial frictions new born firms would be able to borrow enough to immediately reach the efficient capital stock level. But entrepreneurs' borrowing is limited to a fraction θ of their capital stock. With the collateral constraint in place entrepreneurs have to slowly accumulate earnings until they reach the optimal stock of capital.

[16] In the empirical part I am using data from publicly traded firms which are quite different from entrepreneurs. Unfortunately there is no loan contract data available publicly for private firms and even credit registry data usually has no information about covenants. Appendix 1.8.5 shows some anecdotal evidence that loans for small firms do contain covenants.

The novel part of the model is the earnings covenant. The earnings covenant matters for the tightness of the collateral constraint θ. In this model, θ can take two values $\{\theta_{LOOSE}, \theta_{TIGHT}\}$. I will discuss the determination of θ and the probability next period's θ, $\pi_{\theta'}$, in detail below. For now, with θ and $\pi_{\theta'}$ given, the entrepreneur's problem is standard. Entrepreneurs, who know they will not exit this period, maximize their flow utility and expected continuation value with respect to consumption, next period capital and next period debt:

$$V(k,b,z,\theta) = \max_{c,k',b'} \frac{c^{1-\sigma}}{1-\sigma} + \beta \sum_{\theta'} \pi_{\theta'} \sum_{z'} \pi_{z'|z} V(k',b',z',\theta')$$

subject to:

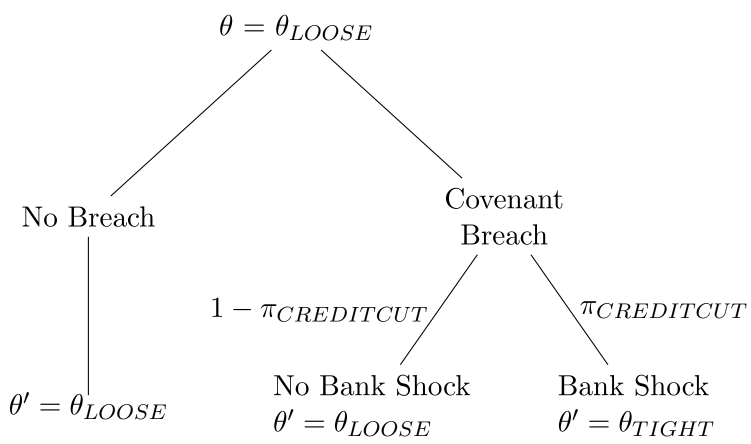
$$c + i \leq zk^{\alpha} + \frac{1}{1+r}b' - b - \Phi(i)$$

$$i = k' - (1-\delta)k$$

$$b' \leq \theta k,$$

where β denotes the discount factor. Entrepreneurs finance their consumption and investment using the output from production and net borrowing. Investment is subject to an adjustment cost $\Phi(i)$ and next period borrowing b' is limited to a fraction θ of the firm's current capital stock. Without an earnings covenant θ remains constant over time and the model collapses to the standard model.

Figure 1.6: Evolution of the entrepreneur's collateral constraint tightness θ



The earnings covenant In this model entrepreneurs are subject to an earnings covenant in addition to the collateral constraint. The earnings covenant is a threshold $\hat{y}$ which specifies the maximal ratio of debt/earnings:

$$\frac{b}{y} < \hat{y}.$$

I model the earnings covenant as a maximal debt/ebitda ratio because it is the most common type of earnings covenant in the data. When an entrepreneur's debt/earnings ratio is lower than the earnings covenant threshold $\hat{y}$ the entrepreneur's collateral constraint tightness is θ_{LOOSE}. This corresponds to the left-hand side branch in Figure 1.6.

When the debt/earnings ratio exceeds $\hat{y}$ the entrepreneur breaches the covenant. In reality, a bank has the possibility to call back the entire loan or change the terms of the loan after a covenant breach. The bank can also not act and waive the breach. In the model a bank has only two options: it can either reduce the firm's credit limit by setting a tighter collateral constraint θ_{TIGHT} or it can waive the covenant breach and keep $\theta = \theta_{LOOSE}$. I assume that banks tighten a firm's credit limit after a covenant breach with an exogenous probability $\pi_{CREDITCUT}$.

The empirical literature provides evidence that covenants reduce firms' borrowing costs ex-ante[17]. This suggests that lowering a firm's credit limit after covenant breach is efficient in some states, for example to avoid bankruptcy. A different literature points to bank health as an important determinant of credit line cuts after a covenant breach. The empirical evidence by Chodorow-Reich and Falato (2017) documents how banks use covenant breaches to tighten the credit supply to firms when they suffer losses which are not directly related to the borrower's health. In these states credit limit cuts after covenant breaches seem to be inefficient.

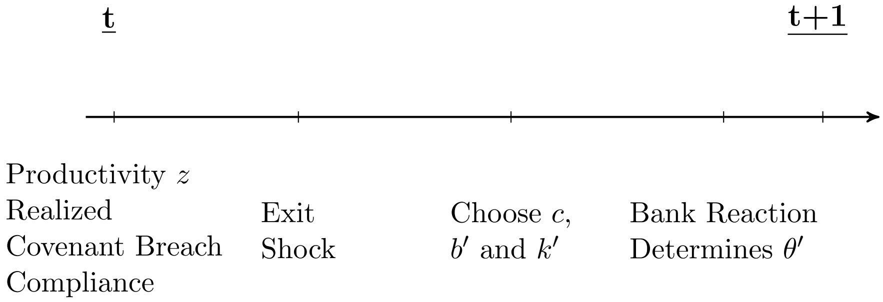
Because in this model entrepreneurs never default the tightening of the borrowing constraint is always inefficient. I take this short-cut to keep the model tractable and to make the model comparable to most of the existing literature on financial friction in heterogeneous firm models. The right hand side branch of Figure 1.6 summarizes the steps of how the tightness of a firm's collateral constraint is determined after a covenant breach.

As in the data, entrepreneurs might remain stuck with a tighter collateral constraint once the bank has tightened their collateral constraint. The probability π_{STAY} determines whether the entrepreneur keeps the tight collateral constraint θ_{TIGHT} or is able to borrow with tightness θ_{LOOSE} again.

Timing Figure 1.7 shows the timing of events in the model: First, firm-specific productivity is realized, which determines whether the entrepreneur breaches the covenant or not. Then the entrepreneur learns whether he will be forced to exit this period. The

[17]See Green (2018) and Matvos (2013)

Figure 1.7: Timing



entrepreneur then decides about consumption, next period debt and capital. Finally, the bank loss shock is realized: when the entrepreneur has breached a covenant, the bank shock determines if the bank cuts the entrepreneur's next period credit or not.

Entrepreneurs in this model do not know their productivity when taking the borrowing and investment decision. This assumption is important as it makes it more difficult for firms to avoid a covenant breach.

1.5.2 Model Evaluation

I will evaluate the performance of the earnings covenant model by comparing it to three other models. First, to highlight the difference between the earnings covenant model and models with standard financial frictions I will solve a model with collateral constraints, i.e. a constant $\theta = \theta_{TIGHT} = \theta_{LOOSE}$. This model will allow me to compare the results of the earnings covenant model against the model used by a large part of the existing literature on financial frictions with heterogeneous firms. Second, I will solve a model with a net worth covenant. The net worth covenant is specified as the maximal ratio of debt/capital, that is:

$$\frac{b}{k} < \hat{a}.$$

Although net worth covenants have almost disappeared in the data (see Figure 1.11), a net worth covenant model is useful to highlight the difference between a covenant on a flow variable against a covenant on a stock variable. Finally I will also solve the model without any financial frictions to provide a benchmark.

1.5.3 Calibration

The parameters of the model are set in three different ways. The first and second group of parameters are not calibrated. The first group of parameters is set to values commonly used in the literature. The second group is set to their empirical counterparts. The third group, the calibrated parameters, is set to target a moment.

Non-calibrated parameters Table 1.9 shows all non-calibrated parameter values. I set the discount factor β, returns to scale α, depreciation δ, exit rate γ and relative risk aversion σ to values commonly used in the literature. I estimate firm-level productivity z_{ist} on the full Compustat sample between 2004 and 2007. The input elasticity is allowed to vary across 40 Fama-French industries. The details of the productivity estimation can be found in Appendix 1.8.7. Then I estimate the following AR1 process:

$$log(z_{ist}) = \rho_z log(z_{ist-1}) + \epsilon_{ist}.$$

I obtain a persistence parameter ρ_z of 0.7 and a standard deviation of productivity shock σ_z to be 0.23.

The remaining non-calibrated parameters determine the cost of an earnings covenant breach. I use the data on credit lines and covenant breaches provided Sufi (2009). The author provides information on credit limits, the used portion of the credit limit and whether or not a firm is breaching a covenant for 300 randomly chosen firms. The data set covers the period from 1996 until 2003. Although this data set contains the 2001 recession, it is better suited for determining steady state parameter values than the credit limit data from the Great Recession.

To set the probability of a credit line cut conditional on the firm having breached a covenant $\Pi_{CREDITCUT}$ I compute the probability of a firm having a credit line decrease of more than 25% one year after breaching a covenant. In Sufi (2009) this probability is 29%. I set the probability of remaining with a tight collateral constraint $\Pi_{CREDITCUT}$ to 25%. The parameter θ_{TIGHT} determines the tightness of the collateral constraint after a bank cuts the firm's credit. I set θ_{TIGHT} to the median ratio of total used debt plus unused debt capacity divided by the capital stock one year after a covenant breach. In the data this ratio equals 1.2. Including the unused debt capacity is important because it is less dependent on a firm's credit demand than used debt. The parameter θ_{LOOSE} determines the tightness of the collateral constraint when the firm does not experience a credit cut. In the data I compute the distribution of the used fraction of credit lines when firms do not breach a covenant and I find that only 3% of firms use the total amount of their credit line (see Figure 1.15). Therefore the credit limit seems non-binding for most firms and I set θ_{LOOSE} to infinity.

Calibrated parameters I set the earnings covenant threshold $\hat{y}$ to 2.375 to match aggregate leverage in the data. The earnings covenant threshold determines the maximal ratio of debt/earnings firms are allowed to have without breaching the covenant. This value for $\hat{y}$ seems realistic because in the data the mode of the debt/earnings threshold value is 3. The tightness of the collateral constraint θ in the collateral constraint model is set to 1.479 to match aggregate leverage. The value for θ is not too far from the tightness of the collateral constraint set to 1.380 during normal times in Khan and Thomas (2013).

I target leverage for both models to make them comparable.

In the data, the average firm with an earnings covenant is different from the average firm with a net worth covenant. Firm with earnings covenants are larger and have higher leverage, for example. Therefore firms seem to select into different contract types depending on their characteristics. On the other hand a number of firms has switched the type of contract during the 2000s. Because I want to compare the earnings covenant model against the net worth covenant model without explicitly modeling the difference between the two types of covenants[18], I set the debt/capital covenant threshold $\hat{a}$ such that the cost in terms of investment in the net worth covenant model equals the cost in the earnings covenant model. The cost in terms of investment is measured relative to the model without financial frictions.

1.6 Results

This section presents the steady-state results of the earnings covenant model. First, I document the aggregate cost of earnings covenants in terms of investment and the decomposition into a direct and an indirect cost. Then I simulate the model and analyze the implications of the earnings covenant at the firm level. Throughout this Section I compare the earnings covenant model against the model with a collateral constraint only and the net worth covenant model.

1.6.1 Aggregate Results

Table 1.11 compares the aggregate variables of the three different model economies to the benchmark economy without financial frictions. For each model m and variable x I first aggregate over idiosyncratic states as follows:

$$X^m = \int_{k,b,z} x^m_{k,b,z} f(k,b,z)^m dk\, db\, dz$$

where $f(k,b,z)^m$ is the steady state firm distribution.

Then I compute the percentage distance of the aggregate variable from the model without financial frictions:

$$\Delta X^m = \frac{X^m - X^{\text{No Friction}}}{X^{\text{No Friction}}}$$

The first column of Table 1.11 presents the results for the earnings covenant model. Investment in the model with earnings covenants is 1.3% lower relative to the economy

[18] Christensen and Nikolaev (2012) find that financially constrained firms and firms with better quality accounting information are more likely to have earnings covenants, Honigsberg and Sadka (2014) find that the state law matters for the covenant type. Demerjian (2011) argues that increased mark-to-market of balance sheet items has led to the decline in net worth covenants.

without financial frictions. In the model the share of firms breaching a covenant each year is 12%. This is close to the average of 10% I find in the data. Only 2.1% of firms face a binding collateral constraint in the earnings covenant model. This number is low for two reasons: first, only a subset of firms breaching a covenant has its credit limit cut by the bank and second, not all firms with a tight collateral constraint have a high borrowing demand.

The second and third columns of Table 1.11 show the results for the net worth covenant and the collateral constraint economy. Comparing the cost of financial frictions in terms of aggregate investment across the three different types of frictions, the collateral constraint imposes the largest cost with investment being 2.7% below the model without financial frictions. The corresponding number for the net worth covenant model is 1.8%, which is larger than in the earnings covenant model. In the net worth covenant economy, only 2% of firms are breaching a covenant each year and only 0.6% of firms have a binding collateral constraint. In the collateral constraint model almost a third of firms faces a binding collateral constraint. This is more than ten times more compared to the models with covenants. The large difference in the share of constrained firms does not map into an equally large loss in terms of aggregate investment which is only about two times lower in the collateral constraint model. There are two main explanation for this difference: first, the set of firms with binding constraints is different across the models, and second, covenants reduce investment relative to the model without financial frictions even when firms are not facing a binding constrained.

Table 1.12 compares firms with a binding collateral constraint across the different models. The average firm with a binding constraint in the earnings covenant model has a higher capital stock, a higher level of debt and lower productivity compared to firms with binding constraints in the net worth covenant and the collateral constraint model. The characteristics of constrained firms in the net worth covenant model and the collateral constraint model are relatively similar. But because the share of constrained firms is almost 50 times larger in the collateral constraint model the small overall difference in the investment cost cannot be explained only by the different set of firms with binding constraints.

The second explanation is that covenants change firms' investment even when firms are not at the constraint. To investigate the possibility I decompose the total cost in terms of investment into a direct effect, i.e. lower investment of firms facing a binding collateral constraint, and a precautionary effect. The precautionary effect comes from firms lowering investment *before* hitting the collateral constraint. For the decomposition I use the firm size distribution of the corresponding model with financial frictions. I compute the following aggregate statistic:

$$\tilde{\Delta} I^m = \int_{k,b,z} \left(i^m_{k,b,z} - i^{\text{No Friction}}_{k,b,z} \right) f(k,b,z)^m dk\, db\, dz / I^{\text{No Friction}},$$

with $i^m_{k,b,z}$ the firm-level investment in the model with financial frictions, $i^{\text{No Friction}}_{k,b,z}$ firm-level investment in the model without financial frictions and $I^{\text{No Friction}}$ aggregate investment in the model without financial frictions.

Then I compute $\tilde{\Delta} I^m_{Binding}$ and $\tilde{\Delta} I^m_{NotBinding}$ by including an indicator for firms with binding collateral constraints. Because the steady state firm size distributions are different across models the aggregate cost ΔI^m reported in Table 1.11 is different from $\tilde{\Delta} I^m$.

Table 1.13 shows the results of the decomposition. In the two economies with covenants the precautionary cost is larger than the direct cost and accounts for 80% of the total cost in the earnings covenant model and more than 92% of the total cost in the net worth model. In the collateral constraint model the proportion is reversed: 65% of the total cost is due to the direct effect. This is surprising because the finance literature has almost exclusively focused on the direct effect of covenants on investment through covenant breaches.

To shed light on the difference in firm behavior in economies with different financial frictions and evaluate the model performance at the firm-level I simulate all economies to obtain four panel data sets with firm-level data.

1.6.2 Firm-Level Results

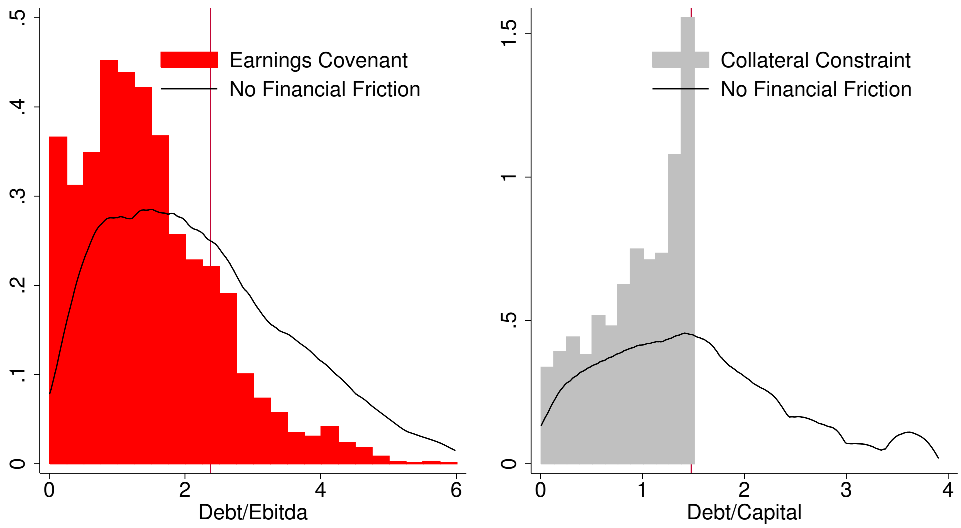
In this section I use the simulated firm-level data to compare the results against actual firm-level data. First, I highlight the difference between covenants and constraints comparing the distribution of the accounting ratios used in the covenant or the constraint. Second, I evaluate the direct and precautionary cost at the firm-level by re-running the regression of Table 1.6 on the simulated earnings covenant model data.

Graphical Evidence The difference between covenants and constraints becomes apparent when I compare the distribution of debt/earnings in the earnings covenant model and debt/capital in the collateral constraint model. The right-hand side panel of Figure 1.8 shows that firms in the collateral constraint model bunch close to the constraint[19]. Firms at the constraint would increase their debt holdings if the collateral constraint was looser. In the left-hand side panel of Figure 1.8 firms in the earnings covenant model bunch at a distance to the earnings covenant threshold. Firms could increase their debt holdings but if they did, they would increase the risk of a covenant breach. Firms to the right of the covenant threshold are in breach of the covenant.

As a next step, I compare the debt/earnings distribution normalized by the covenant of the simulated data against actual data of firms subject to a Debt/Earnings covenant. In Figure 1.9 the distribution using the actual data resembles the distribution of the simulated data.

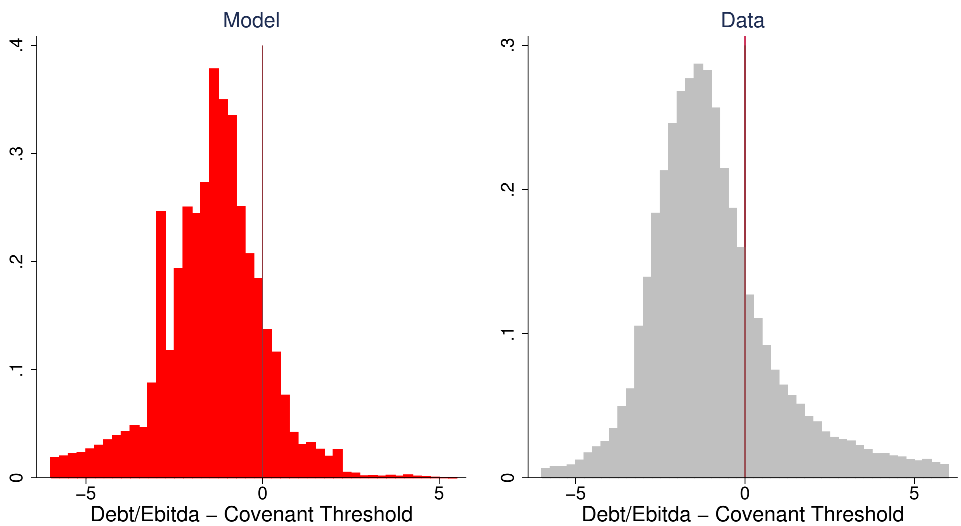
[19]The spike is due to the mass of new-born firms at a this level of debt/capital

Figure 1.8: Simulated Data: Debt/Earnings and Debt/Capital



Notes: The left-hand-side panel compares the distribution of Debt/Earnings of the earnings covenant Model against the Frictionless Benchmark Model. The red line shows the earnings covenant threshold. The right-hand-side panel compares the distribution of Debt/Capital of the Collateral Constraint Model against the Frictionless Benchmark Model. The red line shows the collateral constraint.

Figure 1.9: Simulated Data: debt/earnings and debt/capital



Notes: Both panels show the distribution of debt/earnings minus the earnings covenant threshold. The left hand side panel uses the simulated data, the right hand side panel actual firm-level data. Firms with a normalized debt/earnings ratio above zero are breaching a covenant.

Regression I now run the same regression on the simulated earnings covenant model data as in Section 1.4.2. Except for the control variables I use the same variables as in the regressions with the actual data. Columns one and two of Table 1.14 show that a covenant breach has a significant negative impact on the investment rate. A covenant breach reduces the investment rate by 1.725 percentage points, which corresponds to 9.5% of the mean and 6.8% of the standard deviation.

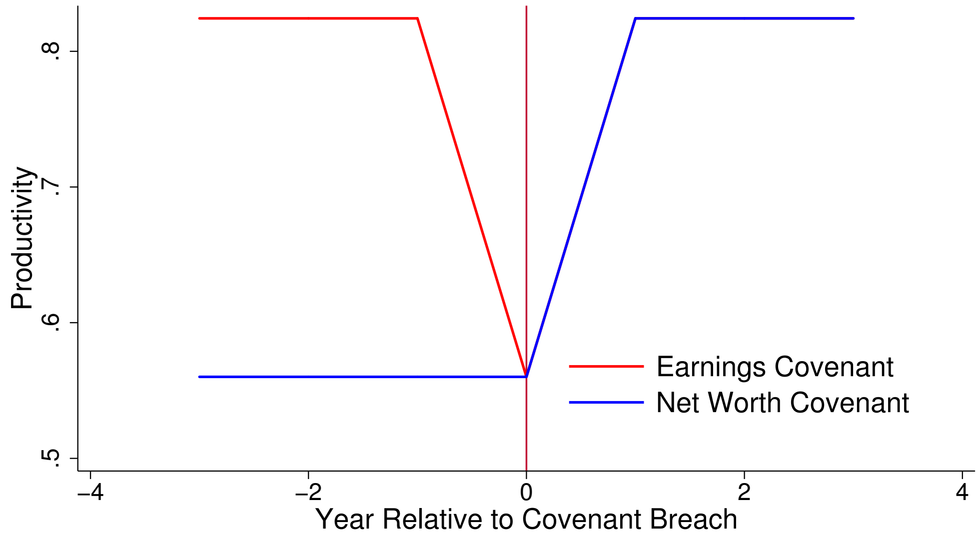
As in the actual data I use the log difference to the covenant threshold as a measure of the importance of the precautionary cost at the firm level. Columns three and four of Table 1.14 show an increase in the log distance to the covenant threshold has a significant positive impact on the investment rate. A one standard deviation increase in the log distance to the covenant threshold increases the investment rate by 2.996 percentage points, which corresponds to 6.9% of the mean and 4.9% of the standard deviation of the investment rate.

Table 1.15 compares the size of the coefficients between the regressions on actual data against the regression using the simulated data from the earnings covenant model. The coefficients from the actual data are relatively close to those from the simulated data. Because the coefficients have not been targeted in the calibration, this validates the model.

Difference between Earnings and Net Worth covenants The investment loss in the net worth covenant model from the precautionary effect is larger than in the earnings covenant model. This could be because a different set of firms is affected by earnings and net worth covenants. Table 1.16 compares firm characteristics of firms breaching a covenant across both models. Firms breaching a covenant in the earnings covenant model have a higher capital stock and also more debt. They are also less productive than firms breaching a covenant in the net worth covenant model.

Because earnings are more volatile than capital, it might be more difficult for firms to avoid a covenant breach in the earnings covenant model. In the net worth covenant model, avoiding a breach is easier. This could account for the larger share of the precautionary cost of the total cost in the net worth covenant model. In the simulated data I can follow the productivity of firms breaching a covenant. I select all firms breaching a covenant and then compute the median productivity around the covenant breach. Figure 1.10 shows firms in the net worth covenant model that are breaching a covenant are at the lowest productvitiy level three years before the breach happens. Firms in the earnings covenant model breach a covenant when their productivity drops during only one period: the year when they breach a covenant.

Figure 1.10: Simulated Data: Productivity around Covenant Breach



Notes: This Figure shows the productivity of the median firm breaching a covenant in year=0. The red line is the median in the earnings covenant model and the blue line the median in the net worth covenant model.

1.7 Conclusion

This paper analyzes the impact of financial covenants on firm behavior, in particular the cost in terms of investment. Financial covenants are conditions present in almost all loan contracts a borrower must satisfy, otherwise the bank can call back the loan.

I start by showing that most firms are subject to financial covenants and most covenants are conditions on a firm's earnings. Using hand-collected data on firm's credit line limits and data on covenant thresholds I provide evidence that earnings covenants can account for a large fraction of credit line cuts during the Great Recession.

Based on these facts, I incorporate earnings covenants into an otherwise standard model with heterogeneous firms. In the model as in the data, firms getting closer to their covenant threshold reduce investment. I call this the precautionary cost of covenants on investment. There is an additional, direct cost coming from the lower credit supply after a firm has breached a covenant. When I calibrate the model to the sample of US public firms I find that the aggregate cost of earnings covenants in terms of investment is 1.3% relative to a model without financial frictions. I also find the cost from precaution to be higher than the direct cost. Regressions on simulated model data yield coefficients (not targeted in the calibration) close to the ones from regression on actual data, thus validating the ability of the model to generate realistic firm behavior.

I compare the earnings covenant model's prediction against two alternative models: one with a traditional collateral constraint and a second model with a net worth covenant. The three models yield different predictions about firm behavior, which highlights the importance of distinguishing between covenants and constraints on the one hand, as well as between covenants based on a flow variable (earnings) and a stock variable (net worth).

Bibliography

Aghion, P. and Bolton, P. (1992). An incomplete contracts approach to financial contracting. *The Review of Economic Studies*, 59(3):473.

Aiyagari, S. R. (1994). Uninsured Idiosyncratic Risk and Aggregate Saving. *The Quarterly Journal of Economics*, 109(3):659–684.

Atkeson, A. G., Eisfeldt, A. L., and Weill, P.-O. (2017). Measuring the financial soundness of U.S. firms, 1926–2012. *Research in Economics*, 71(3):613–635.

Bernanke, B. and Gertler, M. (1989). Agency Costs, Net Worth, and Business Fluctuations. *American Economic Review*, 79(1):14–31.

Buera, F. J. and Moll, B. (2015). Aggregate Implications of a Credit Crunch: The Importance of Heterogeneity. *American Economic Journal: Macroeconomics*, 7(3):1–42.

Catherine, S., Chaney, T., Huang, Z., Sraer, D. A., and Thesmar, D. (2018). Quantifying reduced-form evidence on collateral constraints.

Chava, S. and Roberts, M. R. (2008). How Does Financing Impact Investment? The Role of Debt Covenants. *Journal of Finance*, 63(5):2085–2121.

Chodorow-Reich, G. and Falato, A. (2017). The Loan Covenant Channel: How Bank Health Transmits to the Real Economy. NBER Working Papers 23879, National Bureau of Economic Research, Inc.

Christensen, H. B. and Nikolaev, V. V. (2012). Capital Versus Performance Covenants in Debt Contracts. *Journal of Accounting Research*, 50(1):75–116.

Demerjian, P. R. (2011). Accounting standards and debt covenants: Has the "balance sheet approach" led to a decline in the use of balance sheet covenants? *Journal of Accounting and Economics*, 52(2):178 – 202.

Demerjian, P. R. and Owens, E. (2014). Measuring financial covenant strictness in private debt contracts. *SSRN Electronic Journal*.

Dewatripont, M. and Tirole, J. (1994). A Theory of Debt and Equity: Diversity of Securities and Manager-Shareholder Congruence. *The Quarterly Journal of Economics*, 109(4):1027–1054.

Drechsel, T. (2018). Earnings-Based Borrowing Constraints and and Macroeconomic Fluctuations. *Mimeo.*

Falato, A. and Liang, N. (2016). Do creditor rights increase employment risk? evidence from loan covenants. *The Journal of Finance*, 71(6):2545–2590.

Gopinath, G., Şebnem Kalemli-Özcan, Karabarbounis, L., and Villegas-Sanchez, C. (2017). Capital Allocation and Productivity in South Europe. *The Quarterly Journal of Economics*, 132(4):1915–1967.

Graham, J. R., Harvey, C. R., and Rajgopal, S. (2005). The economic implications of corporate financial reporting. *Journal of accounting and economics*, 40(1-3):3–73.

Green, D. (2018). Corporate refinancing, covenants, and the agency cost of debt. *Mimeo.*

Honigsberg, Colleen; Katz, S. and Sadka, G. (2014). State contract law and debt contracts. *Journal of Law and Economics.*

Khan, A. and Thomas, J. K. (2013). Credit Shocks and Aggregate Fluctuations in an Economy with Production Heterogeneity. *Journal of Political Economy*, 121(6):1055–1107.

Kiyotaki, N. and Moore, J. (1997). Credit Cycles. *Journal of Political Economy*, 105(2):211–248.

Lian, C. and Ma, Y. (2018). Anatomy of corporate borrowing constraints. *Mimeo.*

Matvos, G. (2013). Estimating the Benefits of Contractual Completeness. *Review of Financial Studies*, 26(11):2798–2844.

Murfin, J. (2012). The Supply-Side Determinants of Loan Contract Strictness. *Journal of Finance*, 67(5):1565–1601.

Nini, G., Smith, D. C., and Sufi, A. (2009). Creditor control rights and firm investment policy. *Journal of Financial Economics*, 92(3):400–420.

Nini, G., Smith, D. C., and Sufi, A. (2012). Creditor Control Rights, Corporate Governance, and Firm Value. *Review of Financial Studies*, 25(6):1713–1761.

Sufi, A. (2009). Bank Lines of Credit in Corporate Finance: An Empirical Analysis. *Review of Financial Studies*, 22(3):1057–1088.

Terry, S. J. (2017). The macro impact of short-termism. *Mimeo.*

1.8 Appendix

1.8.1 Tables

Table 1.1: Firm characteristics: Credit limit sample Great Recession

	Mean	Median
Has line of credit	1.00	1.00
Credit limit/assets	1.26	0.17
Credit limit decrease	0.06	0.00
Credit limit decrease > 25%	0.04	0.00
Covenant breach	0.09	0.00
First covenant breach	0.05	0.00
Any breach during GR	0.17	0.00
Log assets	6.57	6.75
Market to book value	1.55	1.27
Leverage	0.26	0.24
Cash/assets	0.11	0.07

Notes: This table provides summary statistics for the sample of firms with manually collected data about firms' credit limits during the Great Recession. The sample contains 848 firms and 2540 firm-year observations.

Table 1.2: Dependent Variable: Credit Line Decrease

	(1)	(2)
Earnings	-1.531**	-1.255
	(0.77)	(0.78)
Net Worth	-0.685	-0.662
	(0.86)	(0.85)
Covenant Breach		1.922*
		(0.98)
Industry FE	Y	Y
R^2	0.0366	0.0438
N	1356	1356

Notes: This table shows two linear probability models with *Credit Line Decrease* as dependent variable. *Credit Line Decrease* equals one if a firm has a 25% reduction in its credit line scaled by its total assets in 2006 during the Great Recession. *Earnings* are earnings/assets centered and standardized using the 2006-2003 average and standard deviation of earnings/assets. *Net Worth* is (assets - debt)/assets centered and standardized using the 2006-2003 average and standard deviation. Both *Earnings* and *Net Worth* are winsorized at 5%. Standard errors clustered at the firm-level in parentheses.

Table 1.3: Dependent Variable: Credit Line Decrease

	(1)	(2)
Covenant Breach	-1.938	2.475*
	(2.20)	(1.33)
Bad Lender x Covenant Breach	5.043**	
	(2.20)	
Bad Lender	0.294	
	(0.67)	
Industry FE	Y	Y
R^2	0.0773	0.0614
N	1005	1005

Notes: This table shows two linear probability models with *Credit Line Decrease* as dependent variable. *Credit Line Decrease* equals one if a firm has a 25% reduction in its credit line scaled by its total assets in 2006 during the Great Recession. *Bad lender* is the scaled principal component of 1) the fraction of a bank's syndicated loan portfolio where Lehman Brother's had a lead role and 2) the correlation of the bank's daily stock return on the ABX AAA 2006-H-1 index as in Chodorow-Reich and Falato (2017). The variable is then matched to firms using a weighted average, where the weights depend on a bank's syndication share. Standard errors clustered at the firm-level in parentheses.

Table 1.4: Reduced Form Model Probabilities

Probability	Value
$P(\text{Covenant})$	0.8
$P(\text{Income Covenant}\mid\text{Covenant})$	0.8
$P(\text{Covenant Breach})_i$	Bin-Specific
$P(\text{Credit Cut}\mid\text{Breach}) - P(\text{Credit Cut}\mid\text{No Breach})$	0.095 - 0.046

Notes: This table shows the probabilities used to extrapolate the probability of a credit line decrease due to an income covenant from the sample with data on covenant thresholds to the full sample. Sufi (2009) reports that 80% firms have a credit line. Therefore I set $P(\text{Covenant})$ to this value. The fraction of firms with income covenants $P(\text{Income Covenant}\mid\text{Covenant})$ is taken from the aggregate data on contracts. $P(\text{Credit Cut}\mid\text{Breach})$ is the frequency of credit line decreases of firms with debt/ebitda normalized by the covenant threshold below zero. $P(\text{Credit Cut}\mid\text{No Breach})$ is the frequency of of credit line decreases of firms with debt/ebitda normalized by the covenant threshold above zero.

Table 1.5: Covenant Type Frequency

N	**Frequency**	**Covenant**
7905	51.45	Debt To Ebitda
5758	37.47	Interest Coverage
5083	33.08	Fixed Charge Coverage
3267	21.26	Tangible Net Worth
2903	18.89	Capital Expenditures
2666	17.35	Leverage Ratio
2664	17.34	Net Worth
2011	13.09	Debt To Tangible Net Worth
1900	12.37	Current Ratio
15365		Total

Notes: This table shows the frequency of the most common types of covenants in the matched DealScan-Compustat data 1990-2015. See Table 1.20 for how these covenants are defined.

Table 1.6: Dependent Variable: Investment/Capital

	(1)	(2)	(3)	(4)
First Breach	-2.606***	-1.149***		
	(0.41)	(0.39)		
Log Distance to Threshold			0.869***	0.518***
			(0.16)	(0.15)
Log Distance to Threshold < 0			-2.177***	-1.188***
			(0.28)	(0.29)
No Debt/Ebitda Covenant			-0.0435	0.135
			(0.33)	(0.32)
Debt/Ebitda			0.00203	0.00251
			(0.00)	(0.00)
Breach			-1.475***	-0.553
			(0.37)	(0.37)
Controls	N	Y	N	Y
Firm & Year FE	Y	Y	Y	Y
R^2	0.653	0.694	0.657	0.674
N	18680	18680	18680	18680

Notes: This table shows the firm-level regression result with investment/capital as dependent variable. *First Breach* is a dummy for the first covenant breach with at least one year of no covenant breach. *Log distance to Threshold* is the log distance between a firm's debt to earnings and the covenant threshold if the distance is positive. Data are from US public firms 1995-2014. Controls: Log Assets, Leverage, Return on Assets, Market Value/Book Value, Share of Tangible Assets, Sales Growth, Cash Flow/Assets, Cash/Assets and Acquisitions/Assets. Additional controls in columns (3) and (4): Debt/Ebitda, and indicators for covenant breach and if the firm has no Debt/ Ebitda covenant. All independent variables are lagged in columns (1) and (2). The dependent variable is winsorized at 5%. Robust standard errors in parentheses. Investment: mean 22.87, sd 15.27, Log distance to threshold if positive: mean 0.04, sd 0.87, Distance to threshold if positive: mean 1.32, sd 0.71

Table 1.7: Dependent Variable: Investment/Capital

	Contract FE	Industry-Year FE	Investment Next Year	No Capex Cov.	
Log Distance to Threshold	0.492***	0.514***	0.318**	0.553***	
	(0.17)	(0.16)	(0.14)	(0.18)	
Std Distance to Threshold					0.120***
					(0.04)
Log Distance to Threshold < 0	-1.134***	-1.200***	-0.781***	-1.418***	-0.610*
	(0.37)	(0.30)	(0.28)	(0.35)	(0.32)
No Debt/Ebitda Covenant	0.487	0.167	0.276	0.392	0.635*
	(0.80)	(0.34)	(0.30)	(0.38)	(0.38)
Debt/Ebitda	0.00772	0.00233	-0.00197	-0.00153	0.00623**
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Breach	-0.130	-0.314	-1.871***	-0.344	-0.496
	(0.52)	(0.38)	(0.35)	(0.47)	(0.41)
Firm & Year FE	-	-	Y	Y	Y
Firm & Industry-Year FE	-	Y	-	-	-
Contract & Year FE	Y	-	-	-	-
R^2	0.772	0.704	0.695	0.691	0.684
N	8743	18590	18680	14689	14491

Notes: This table shows robustness checks for the firm-level regression result with investment/capital as dependent variable. In column (1) I replace firm fixed effects by contract fixed effects. Column (2) includes industry-year fixed effects. In Column (3) the dependent variable is next year's investment/capital. Column (4) excludes firm-years with capital expenditure covenants. Column (5) the distance to the threshold is standardized by the firm-specific standard deviation of debt/earnings. *Log distance to Threshold* is the log distance between a firm's debt to earnings and the covenant threshold. Data are from US public firms 1995-2014. All regressions include the following controls: Log Assets, Leverage, Return on Assets, Market Value/Book Value, Share of Tangible Assets, Sales Growth, Cash Flow/Assets, Cash/Assets, Acquisitions/Assets, Debt/Ebitda, and indicators for covenant breach and if the firm has no Debt/ Ebitda covenant. The dependent variable is winsorized at 5%. Robust standard errors in parentheses.

Table 1.8: Other Dependent Variables

	Shareholder Payout	Net Debt Issuance	Cash to Assets
Log Distance to Threshold	0.0144**	0.586**	0.284***
	(0.01)	(0.24)	(0.10)
Distance to Threshold < 0	-0.0838***	-1.829***	0.0345
	(0.01)	(0.45)	(0.19)
No Debt/Ebitda Covenant	-0.0169	-1.299***	1.197***
	(0.01)	(0.41)	(0.22)
Debt/Ebitda	0.0000187	-0.000729	0.000182
	(0.00)	(0.00)	(0.00)
Breach	-0.0696***	-2.145***	-0.341
	(0.01)	(0.37)	(0.24)
Controls	Y	Y	Y
Firm & Year FE	Y	Y	Y
R^2	0.588	0.326	0.783
N	18665	17737	18611

Notes: The dependent variables are: a dummy for when a firm pays dividends or repurchases its shares (column 1), net debt issuance/total assets (column 2) and cash holdings/total assets (column 3). Data from 1995-2014. Controls: Log Assets, Leverage, Return on Assets, Market Value/Book Value, Share of Tangible Assets, Sales Growth, Cash Flow/Assets, Cash/Assets, Acquistions/Assets, Debt/Ebitda, Breach, No Debt/ Ebitda Covenant. The continuous dependent variables are winsorized at 5%. Robust standard errors in parentheses.

Table 1.9: Non-Calibrated Parameters

Estimated & fixed parameters	Value	Source
Discount factor	$\beta = 0.96$	
Returns to scale	$\alpha = 0.30$	
Depreciation	$\delta = 0.06$	
Exit rate	$\gamma = 0.05$	
Relative risk aversion	$\sigma = 2.00$	
Compustat Sample		
Persistence of productivity process	$\rho_z = 0.70$	Data
Standard deviation of productivity process	$\sigma_z = 0.23$	Data
Sufi (2009) Sample		
Probability of credit line cut	$\pi_{CREDIT\ CUT} = 0.29$	Data
Probability of keeping tight constraint	$\pi_{STAY} = 0.25$	Data
Collateral constraint	$\theta_{TIGHT} = 1.20$	Data
Collateral constraint	$\theta_{LOOSE} = \infty$	Data

Notes: This table shows the non-calibrated parameters. The first set of parameters is set to values commonly used in the literature. The productivity parameters are estimated on the full Compustat sample 2004-2007. The parameters related to the covenant are estimated on the dataset provided by Sufi (2009)

Table 1.10: Calibrated Parameters

Model	Parameter	Moment	Data	Model
Income Model	$\hat{y} = 2.375$	Debt to Assets	32	32
Collateral Constraint	$\theta = 1.479$	Debt to Assets	32	32
Net Worth Model	$\hat{a} = 1.320$	Cost of Covenant in Income Model	-	8.9

Notes: This table shows the parameters calibrated to the data. The income covenant threshold $\hat{y}$ and the tightness of the collateral constraint θ in the collateral constraint model are chosen to match aggregate leverage in the data. The net worth covenant threshold $\hat{a}$ is set such that the aggregate loss in terms of investment relative to the frictionless model equals the loss in the income covenant model.

Table 1.11: Aggregate Variables at the Steady State

Model m	**Income Covenant**	**Net Worth Covenant**	**Collateral Constraint**
$\Delta X^m = \frac{(X^m - X^{No\ Friction})100}{X^{No\ Friction}}$			
Δ Investment	-1.3	-1.8	-2.7
Δ Output	-0.6	-0.9	-1.6
Δ TFP	-0.2	-0.4	-0.8
Share of firms in breach	12.0	2.0	0.0
Share of firms with binding constraint	2.1	0.6	28.5

Notes: This table compares the steady state across the models with income covenants, net worth covenants and a collateral constraint. Investment, Output and TFP are percentage differences relative to the frictionless benchmark economy. TFP is computed as Y/K^{α}. The share of firms breaching a covenant and the share of firms with a binding constraint are in percent.

Table 1.12: Average among Constrained Firms

Model	Capital	Debt	Productivity
Income Covenant	2.04	2.44	0.76
Net Worth Covenant	1.09	1.45	0.80
Collateral Constraint	0.71	0.70	0.95

Notes: This table shows the average capital stock, debt and productivity for firms with a binding collateral constraint for the income covenant model, the net worth covenant model and the model with a fixed collateral constraint.

Table 1.13: Cost of Covenants & Collateral Constraint

Model m	**Income Covenant**	**Net Worth Covenant**	**Collateral Constraint**
Aggregate Loss $\tilde{\Delta} I^m$	-8.9	-8.9	-8.0
Decomposition			
Precautionary $\tilde{\Delta} I^m_{NotBinding}$	-7.2	-8.2	-2.8
Direct Effect $\tilde{\Delta} I^m_{Binding}$	-1.8	-0.7	-5.2

Notes: This table decomposes the loss in terms of investment relative to the frictionless model into a direct and a precautionary effect. The aggregate loss is computed using the firm size distribution of the corresponding model with financial friction:

$$\tilde{\Delta} I^m = \int_{k,b,z} \left(i^m_{k,b,z} - i^{\text{No Friction}}_{k,b,z} \right) f(k,b,z)^m dkdbdz / I^{\text{No Friction}}$$

The direct effect $\tilde{\Delta} I^m_{Binding}$ is the loss in terms of investment of firms facing a binding constraint. The precautionary effect $\tilde{\Delta} I^m_{NotBinding}$ is the aggregate difference compared to the frictionless investment of firms not facing a binding constraint.

Table 1.14: Dependent Variable: Investment/Capital

	(1)	(2)	(3)	(4)
First Breach	-7.944***	-1.725***		
	(0.08)	(0.07)		
Log Distance to Threshold > 0			26.49***	2.996***
			(0.22)	(0.09)
Log Distance to Threshold			-46.23***	-19.15***
			(0.51)	(0.21)
Controls	N	Y	N	Y
Firm FE	Y	Y	Y	Y
R^2	0.268	0.841	0.441	0.922
N	338777	338777	345948	345948

Investment: mean 18.19, sd 25.50, Log distance to threshold > 0: mean 0.99, sd 0.42,

Notes: This table shows the firm-level regression result based on simulated data with investment/capital as dependent variable. *First Breach* is a dummy for the first covenant breach with at least one year of no covenant breach. *Log distance to Threshold* is the log distance between a firm's debt to earnings and the covenant threshold. Controls: Log productivity, log net worth, log capital stock. Additional controls in columns (3) and (4): Debt/Ebitda and a dummy variable indicating a covenant breach. All independent variables are lagged by one year in columns (1) and (2). The dependent variable is winsorized at 5%. Robust standard errors in parentheses.

Table 1.15: Comparison of the coefficients: Data vs Simulated Data

Coefficient size	First Breach	Distance to Threshold > 0
Model	7%	5%
Data	8%	4%

Notes: This table compares the coefficient size between the actual data and the simulated data from the income covenant model. The coefficients are expressed in terms of percentage of the standard deviation of the investment rate. The coefficient size for the distance to the covenant threshold is for a one standard deviation increase in the log distance to the covenant threshold.

Table 1.16: Characteristics of Firms in Covenant Breach

Model	Capital	Debt	Productivity
Income Covenant	2.59	2.76	0.67
Net Worth Covenant	1.04	1.49	0.70
Total	2.37	2.58	0.68

Notes: This table shows the average capital stock, debt and productivity for firms breaching a covenant in the income covenant model and the net worth covenant model.

Table 1.17: Changes in Credit Limit and Type of Covenant Breach

Covenant Type	**N**	**Credit Limit**	**Ebitda**	**Net Worth**
No Breach	944	2		
Breach	224			
Income	87	-32	-138	-35
Unknown	53	-13	-65	-18
Non-Financial	25	0	-14	-10
Leverage	21	-22	-187	-94
Net Worth	17	0	19	-136
Working Capital	16	-6	96	-32
Income + Net Worth	4	-34	2	-168
Several	1	-40		
Total	1168			

Notes: This table shows the relationship between credit limit changes and covenant breaches depending on type of covenant breached for the hand-collected credit limit sample 2007-2009. *Credit Limit* is the percentage change in the credit limit of a firm at the 25th percentile. *Ebitda* and *Net Worth* are the change of the median firm's earnings and net worth divided by the firm-level standard deviation multiplied times 100.

Table 1.18: Firm-level productivity AR1

	(1)	(2)	(3)
	04-07	08-09	04-09
ρ_z	0.684***	0.727***	0.698***
	(35.27)	(29.73)	(45.72)
Constant	0.0582***	0.0150*	0.0404***
	(9.05)	(1.84)	(7.96)
r2	0.506	0.487	0.493
N	1216	933	2149

Notes: This table shows the regression results of an AR1 on the estimated firm-level productivity. t statistics in parentheses

Table 1.19: Standard Deviation of Residuals from Productivity AR1

stats	**sigma1**	**sigma2**	**sigma3**
sd	0.22	0.23	0.23
N	1216.00	933.00	2149.00

Notes: This table shows the standard deviation of the residuals from the regression results of an AR1 on the estimated firm-level productivity. t statistics in parentheses

Table 1.20: Covenant classification

Name	**Compustat data**
Income	
Minimum ebitda	$ebitda_t = \sum_{t=-2}^{1} oibdpq_t$
Debt to ebitda	(dlttq + dlcq)/ebitda
Interest coverage	ebitda/intexp
Fixed charge coverage	ebitda/(intexp + l1.dlcq + xrent)
Debt service coverage	ebitda/(xintq + l1.dlcq)
Net worth	
Net worth	atq - ltq
Minimum tangible net worth	atq - intanq - ltq
Debt to net worth	(dlttq + dlcq)/networth
Leverage ratio	(dlttq + dlcq)/atq
Other	
Current ratio	actq/lctq
Quick ratio	(rectq + cheq)/lctq

Notes: This table shows the mapping of covenants to the data based on Demerjian and Owens (2014) .

1.8.2 Data: details

- **Compustat** Firm accounting data are from Compustat. I keep only firms incorporated in the US and I drop all financial firms with SIC codes 6000-6999.

- **DealScan** I use the covenant thresholds provided by DealScan to compute covenant tightness and to complement the hand-collected data about the type of covenant breached. DealScan data provides information about covenant at the *Package* level. Data about maturity, spreads and the participating banks are at the *Facility* level. Following the literature I merge loan packages with facilities. Then I assume loans are held until maturity and expand all data over the maturity of the facility[20]. This is an important source of measurement error because firms frequently renegotiate loan contracts and DealScan does not provide information about which contract is replaced by a new one. Finally, I merge the DealScan data with Compustat by using the bridge provided by Chava and Roberts (2008).

- **Credit line data 1997-2003** Sufi (2009) provides data about the credit line limit, the used and unused portion as well as covenant breaches for a random subsample of 300 firms. The author kindly made the data available online: https://faculty.chicagobooth.edu/amir.sufi/data-and-appendices/SUFI_RFS_LINESOFCREDIT20070221DATA.dta

- **SEC filings** The covenant breach data and the credit limit during the Great Recession data are based on SEC filings. The quarterly SEC filings are downloaded from EDGAR https://www.sec.gov/edgar/searchedgar/companysearch.html. For reports filed 1996-2008 I use the Compustat-SEC link provided by Nini et al. (2009): faculty.chicagobooth.edu/amir.sufi/data-and-appendices/CSTATSEC_NSS_20091005.dta. For the period 2009-2015 I follow their procedure and build a bridge.

1.8.3 Description of hand-collected data

- **Covenant breaches & reason of breach** I have extended the search alghorithm for covenant breaches by Nini et al. (2012) to include the type of covenant breached and changed the search terms to reduce the number of false positives. I start by extracting all text parts in quarterly and annual filings containing the word "covenant". My search algorithm then has three steps:

  - Filter out conditional statements, for example: "in the event of a covenant violation", "would have been in violation" , "whether or not in compliance" etc[21]

[20] I want to thank Sebastian Doerr for providing codes for the data treatment

[21] Full regular expressions are available upon request

  - Check if the firm reports being in compliance: “in [a-z] compliance”, “the company is presently in complicance” etc.
  - Check if the firms is in breach of a covenant: “failed to meet”, “in technical violation”, “out of compliance” etc.

  When the code finds a covenant violation then, only within the same sentence, I look for an indication of the date, because firms often report covenant breaches that have happened in the past. Also within the same sentence I search for the type of covenant breached.

- **Credit limit**
  - I search all annual and quarterly SEC filings for the following terms:
    * ”(revolving”+s+”){0,1}credit”+s+”(line|facility)”
    * ”working”+s+”capital”+s+”(facility|line)”
    * ”(equipment”+s+”){0,1}(line|lines){1}”+s+”of”+s+”credit”
    * ”revolving”+s+”(loan|credit)”

    and extract and save the part of the filing around these terms. The search terms are loosely based on Sufi (2009).
  - Then I search for the sentences providing the information about the firm’s credit limit(s), for example:
    * “the company’s $30 million credit line”
    * “revolving credit line of $20 millions”

    and verify manually that the extracted information is correct.

1.8.4 Classification of covenants

I use the covenant definitions provided by Demerjian and Owens (2014) to map covenants into Compustat accounting data in Table 1.20.

How reliable is the classification into earnings and net worth covenants? Most covenants can be unambiguously classified into one of the three groups below.“Leverage ratio” can be either debt to net worth or debt to earnings. I therefore checked all occurences of “Leverage ratio” separately for the specific definition. For “Minimum net worth” the amount is often computed using a formula that adds a fraction of income to a fixed amount:

```
(a) tangible net worth not at any time, less than eighty-five percent
(85%) of tangible net worth as of the date hereof (plus seventy-five percent
(75%) of cumulative net income after the date hereof, excluding any fiscal
quarters in which net income is negative
```

A final caveat concerns limits on indebtedness which are not formulated as financial covenants.

1.8.5 Covenants for small businesses and firms outside the US

A large number of websites filled with advice for small business owners of how to cope with covenants suggests that covenants are not only used in loans to large firms. Below is an example from a Forbes article[22] "Bank loan covenants and clauses entrepreneurs regret most":

"[...] Debt Service Coverage Ratio Bank Loan Covenant: To satisfy the bank's level of risk, the bank will set forth a cash flow requirement such as a ratio of income to debt payments which must be maintained by the business throughout the term of the line of credit or loan. For example, the bank may set a debt service coverage ratio of 1.2 which means that the net operating income for a period must exceed the total debt payments (interest and principal) payable to the bank during the same period by 20%. If the total debt payments for the period were $100,000.00, then the business would need to have income equal to $120,000.00 during the same period in order to maintain the bank's debt service coverage ratio covenant. In many cases, the entrepreneur agrees to this covenant and does not understand its meaning or implications should the business have a year with reduced net profit or a loss."

Are loan covenants specific to US banking market? Covenants are common also in France as the following information of a French consulting firm[23] shows:

"Dans le contexte économique actuel de dégradation de la situation financière des entreprises, celles-ci éprouvent les plus grandes difficultés à respecter les covenants figurant dans leurs contrats de prêts. Les covenants sont des clauses, insérées dans des contrats de prêts conclus entre une banque et une entreprise, qui imposent au débiteur le respect de certains engagements spécifiques et notamment de ratios financiers. Le remboursement anticipé du prêt pouvant être la conséquence la plus fréquente du non-respect des objectifs fixés contractuellement."

1.8.6 Earnings covenants and credit line cuts: Alternative approach

Among the 1168 firms[24] in my sample 224 (19%) breach a covenant at least once during the Great Recession. To understand which type of constraint firms were facing I then search for the covenant type breached. Table 1.17 reports the results: Almost 40% of

[22] https://www.forbes.com/sites/hollymagister/2014/01/21/bank-loan-covenants-and-clauses-entrepreneurs-regret- visited on 30.08.2018

[23] https://www.cabinet-oreco.fr/actualites/les-covenants-bancaires-ou-clauses-imposant-a-lemprunteur-de-respe visited 30.08.2018

[24] I exclude firms with a loan size larger 1.8 billion which reduces the sample size from 1238 to 1168

firms in breach were breaching an earnings covenant making this by far the most frequent reason why a firm was breaching a covenant.

The second column in Table 1.17 reports the aggregate change in credit limits for all firms of a category. It does not seem that banks treated earnings covenant breaches differently from other type of breaches. As a comparison firms not breaching a covenant increased their credit limit by 2%.

1.8.7 Firm level productivity

I estimate firm level productivity from Solow residuals by running the following regression using the entire Compustat sample:

$$log(y_{ist}) = \alpha_i + \beta_s^k log(k_{ist}) + \beta_s^l log(l_{ist}) + z_{ist}$$

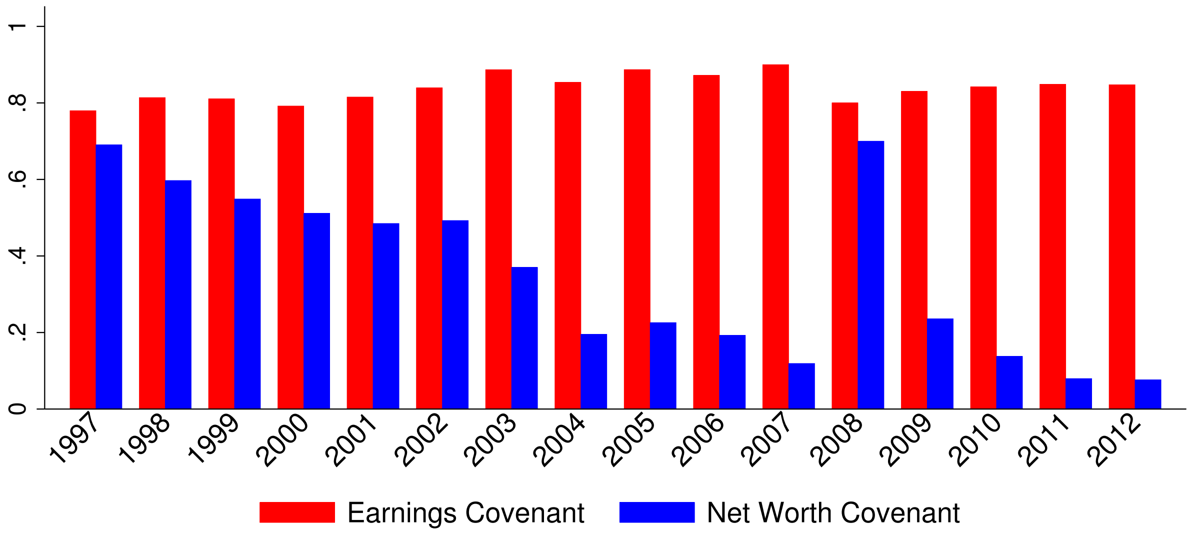
with y_{ist} sales deflated by GDP deflator, k_{ist} the capital stock computed using the perpetual inventory method and l_{ist} the number of employees. I allow factor shares to vary across Fama-French 30 industries indexed by s. I exclude financial firms and utilities as well as firms with negative sales or assets or firms which report an acquisition larger than 5% of their assets.

For the estimation of the productivity process parameters ρ_z, σ_z I then winsorize z_{ist} at 1% and drop all firms with missing values between 2004 and 2010. Table 1.18 and 1.19 report the results.

Both the persistance parameter ρ_z and the standard deviation of innovations σ_z remained relatively stable during the Great Recession whereas average productivity fell to about one quarter, or 43% of the standard deviation of the AR1, of its pre-crisis level. Mean productivity (without taking into account persistence) fell only by about 5%.

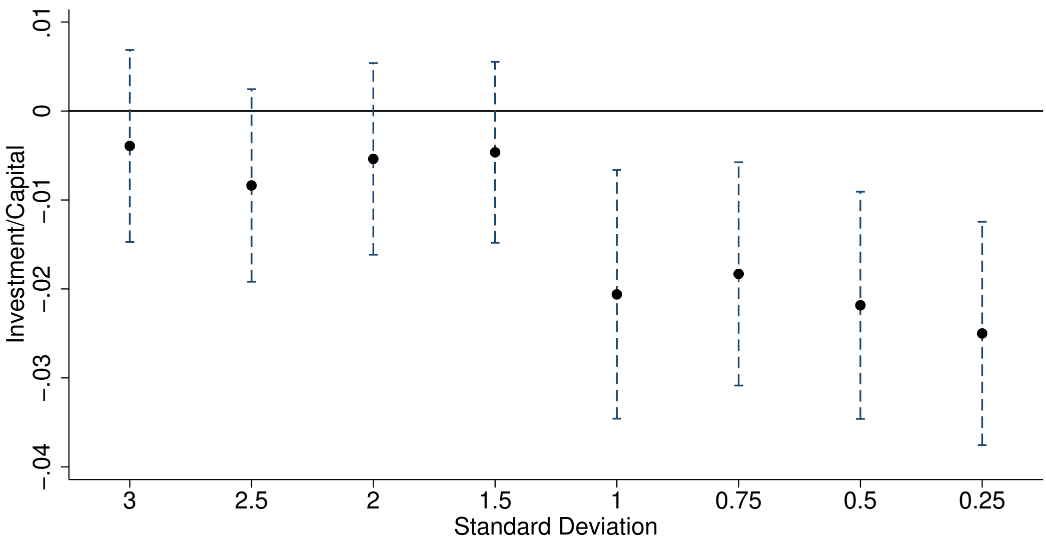
1.8.8 Additional figures

Figure 1.11: Fraction of New Loan Contracts and Covenant Types



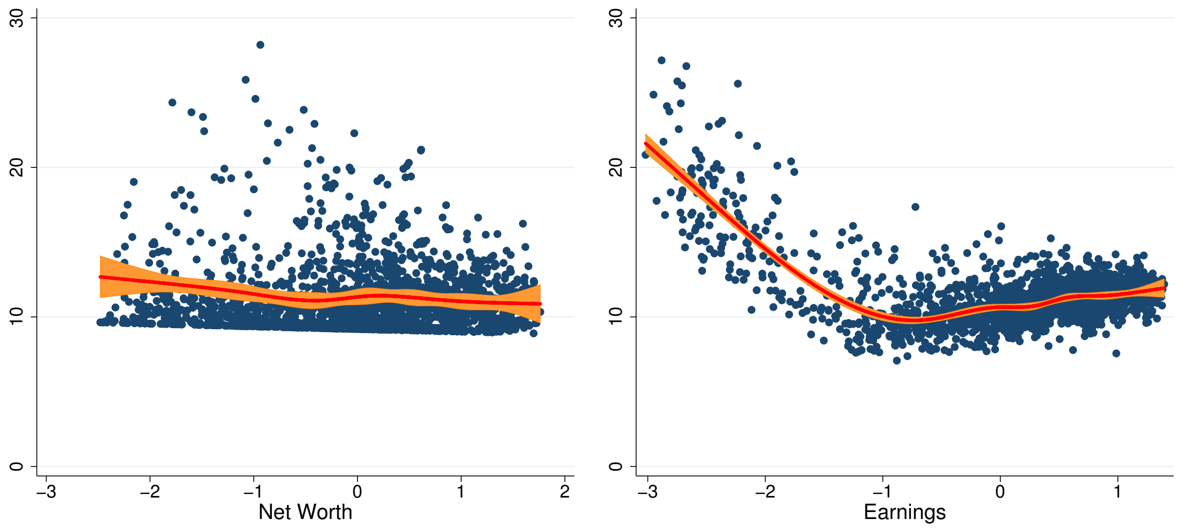
Notes: Fraction of new contracts containing either an earnings or a net worth covenant in a given year. Some contracts contain both, therefore the fractions do not sum up to one. The sample is limited to firms with non-missing data in both DealScan and Compustat. The spike in the fraction of contracts with net worth covenants in 2008 should not be interpreted as a reversal in the trend of fewer net worth covenants, because only few new contracts were initiated in 2008.

Figure 1.12: Distance to Covenant Threshold



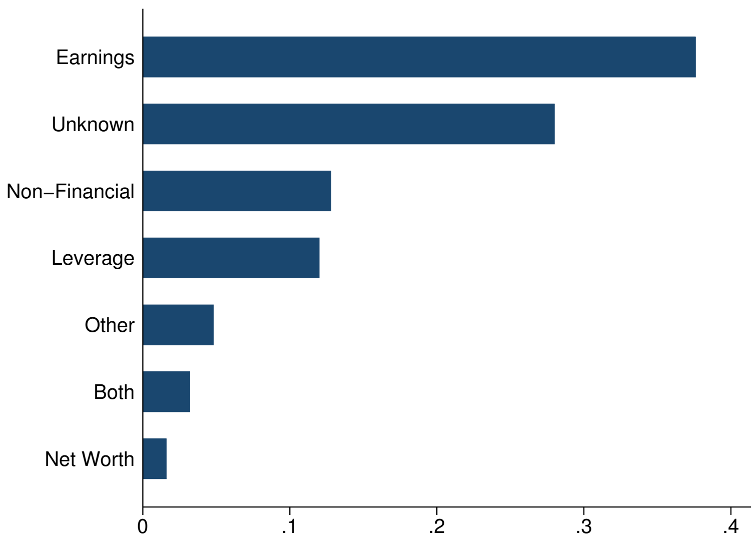
Notes: This graph shows the coefficients from a regression of the distance to the covenant threshold on investment/capital. The distance to the threshold is measured by dummies for firms within 0-0.25, 0.25-0.5, 0.5-0.75, 0.75-1, 1-1.5, 1.5-2, 2-2.5 and 2.5-3 standard deviations of debt/earnings. Data are from US public firms 1995-2014. Controls: Log Assets, Leverage, Return on Assets, Market Value/Book Value, Share of Tangible Assets, Sales Growth, Cash Flow/Assets, Cash/Assets, Acquisitions/Assets, Debt/Ebitda, and indicators for covenant breach and if the firm has no Debt/ Ebitda covenant. The dependent variable is winsorized at 5%. Lines indicate 95% confidence intervals.

Figure 1.13: Predicted Probability of Credit Line Decrease



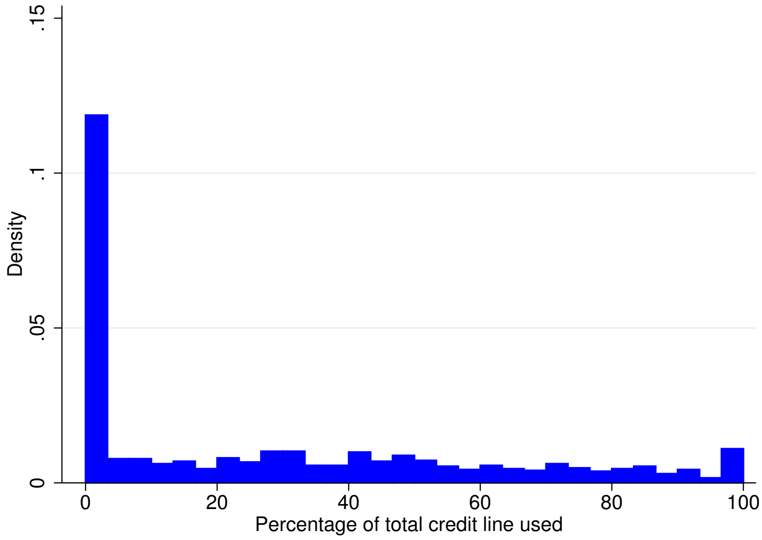
Notes: Relationship between the predicted values from a probit regression of *Credit line decrease* = log(*Net worth*) + log(Assets) on the LHS panel and *Credit line decrease* = log(Earnings) + log(Assets) on the RHS panel. *Credit line decrease* equals one if between 2007-08 or 2008-09 the firm has a decrease in its credit line. *Net worth* is book value of assets minus book value of liabilities. *Earnings* are Earnings before interest, taxes, depreciation and amortization.

Figure 1.14: Covenant Breaches by Type



Notes: Share of firms breaching a certain type of covenant during the Great Recession

Figure 1.15: Percentage of credit line used



Notes: The graph shows the fraction of the credit line used when there was no covenant breach in the previous year. Data are from Sufi (2009)

Figure 1.16: Change in credit limit at firm level during the Great Recession depending on whether the firm has breached a covenant or not.

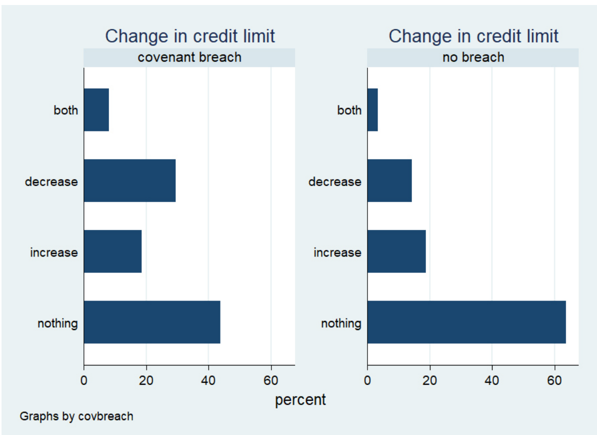
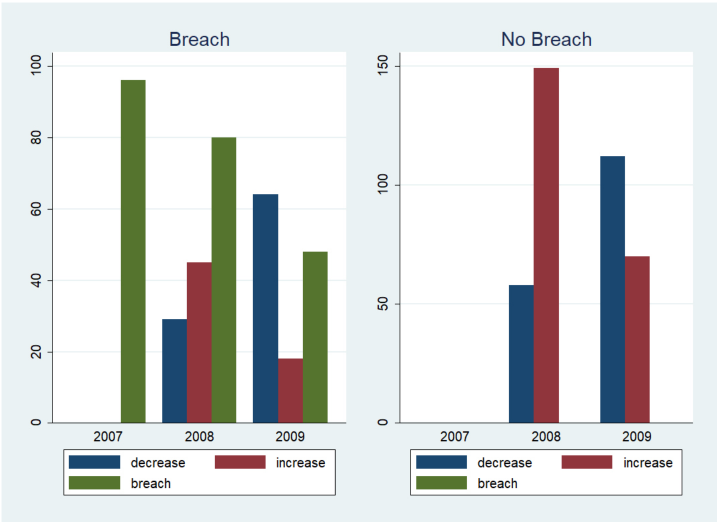


Figure 1.17: Timing of change in credit limit at firm level during the Great Recession depending on whether the firm has breached a covenant or not.



Chapter 2

Innovation and Cash Holdings in the Global Economy

Konrad Adler, JaeBin Ahn, Mai Chi Dao

Abstract

We document a broad-based trend in rising cash holdings of firms across major industrialized countries over the last two decades, a trend that is most pronounced for firms engaged strongly in R&D activities. Our contributions to the literature are twofold. First, we develop a simple model that brings together the insights from modern trade theory (Melitz, 2003) with those of contract theory in corporate finance (Holmström and Tirole, 1998) to show that increased openness to trade can result in rising returns to innovation and in turn greater demand for cash as firms insure against innovation-induced liquidity risk. Second, we derive sharp empirical predictions and find supporting evidence for them using firm-level data across major G7 countries during 1995-2014, a period that saw an unprecedented rise in globalization and business innovation.

2.1 Introduction

Since the early 1990s, the beginning of the most recent era of globalisation, firms in many industrial countries have been holding increasingly more liquid assets.[1] This trend has coincided with a rise in corporate saving globally, such that the corporate sector as a whole is increasingly becoming a net lender to the rest of the economy (Chen, Karabarbounis and Neiman, 2017), and indeed there is evidence that the increase in corporate saving has been used consistently to accumulate cash (Dao and Maggi, 2018). At the aggregate level, we observe that non-financial corporate saving plays a crucial role for current account dynamics, contributing the lion share to the level and change in current account surpluses, particularly among advanced economies (Dao and Maggi, 2018; IMF, 2017). Understanding drivers of corporate liquidity demand will therefore not only allow us to better understand the financing decision of firms, but also reveal important insights into drivers of current account dynamics.

Notwithstanding the importance of this question and the pervasive, global nature of this trend in corporate behavior, we still know little about how corporate saving and liquidity demand are affected by macroeconomic trends and shocks. One salient feature of modern corporations is their growing global exposure and the associated importance of innovation in product development and business operation. The relationship between trade liberalization and innovation is being debated by a rapidly growing literature. There are several competing hypotheses that predict, and empirical evidence that support either a negative relationship between globalization and innovation activity (Autor, Dorn, Hanson, Pisano and Shu, 2016), potentially due to stronger competition in domestic markets and thus a lower payoff from innovation (*'Schumpeterian force'*); or a positive one (Bloom, Draca and van Reenen, 2016), possibly due to domestic firms' desire to upgrade their products' quality to gain an edge amid intensifying import competition (*'escaping competition'*). In a separate literature in corporate finance, the increase in cash holdings has long been documented, and attracted the attention of academic researchers as well as the broader public, even leading to plans for government intervention.[2]. Building on these two strands of literature, our paper delivers two main contributions. First, we show in a simple model of liquidity management how the increase in liquid asset holdings is linked to increased R&D spending when trade costs fall. Unlike most previous papers on trade and innovation, our channel operates through expanding export opportunities rather than increasing import competition, and thus offers a way to reconcile the conflicting evidence from Autor et al. (2016) and Bloom et al. (2016). Second, using firm level

[1] Corporate cash holdings has been extensively analyzed for the U.S. by a growing literature; see Bates, Kahle and Stulz (2009), Pinkowitz, Stulz and Williamson (2016), Graham and Leary (2015) to just mention a few. Studies on this topic for non-US corporates are still few: Iskandar-Datta and Jia (2012), Dao and Maggi (2017) are among the few.

[2] For example, Korean government implemented a tax on corporate cash stocks in 2015 (e.g., *The Economist*, September 27th 2014)

data from a sample of G7 countries we find evidence suggesting that export opportunities, and only to a much smaller extent import competition, are an important driver behind the increase in R&D spending and liquid asset holdings.

In our model, the effect of increased trade openness on rising cash holdings operates through the firm's decision to invest in long-term, risky innovation subject to moral hazard. As globalization is associated with expanding export opportunities, the returns to innovation increase as successful innovators are able to capture a larger market. This first part of the mechanism resembles the effect of exports on innovation in Bonfiglioli, Crino and Gancia (2017), Bustos (2011) and Atkeson and Burstein (2010). Moreover, with investment in innovation being subject to liquidity shocks before the innovation outcome is realized (as in e.g. Aghion, Angeletos, Banerjee and Manova, 2010), the firm must hold enough liquidity to insure against such cost overrun whenever moral hazard prevents it from pledging the full value of the innovation returns to investors. Higher returns to innovation thus induce the firm to hold more cash as they are more likely to innovate, and conditional on being an innovator, to insure against a larger liquidity shock to have more "skin in the game".

We test the main predictions of the model using firm-level data from Thomson Reuters Worldscope, covering mostly large, publicly listed firms in a sample of 5 major advanced economies (the U.S., UK, Japan, France and Germany) during the period 1995-2014. We find that expanding export opportunities and, to a lesser extent, increased import competition, raise cash holdings among incumbent firms. Consistent with the model, the impact on cash holdings is stronger for more productive firms, who are likely to benefit the most from globalization as predicted by the model. Importantly, we also observe that spending on R&D activities increases as firms experience more export opportunities, with the effect again being stronger for more productive firms. Our baseline empirical strategy considers an instrumental variable approach whereby export and import intensity to and from China are instrumented by other countries' respective average values as in Autor, Dorn and Hanson (2013). Alternatively, we measure the reduction in trade cost and associated gains from exporting by using country-industry-specific export tariff rates, computed as a weighted average of trading partners' import tariffs, which strongly confirms the robustness of main results.

On the theoretical front, this paper combines insights from both modern trade theory (Melitz, 2003), and more specifically, models which emphasizes firm heterogeneity and technology adoption (Bustos, 2011; Atkeson and Burstein 2010), with key elements from liquidity management models of corporate finance (Holmström and Tirole, 1998), which rely on the theory of optimal contract to derive the demand for liquidity as an outcome of risky project financing under moral hazard. The innovation of our paper is to combine these two different strands of theoretical literatures and show that globalization, apart from changing the firm-level and industry-wide productivity, can also lead to systematic shifts in corporate balance sheet composition and demand for liquid assets. These shifts, in turn, can have aggregate implications for flow of funds and asset prices. At the same time, our model offers insights that are consistent with the previous literature on the role of finance in exporter selection (e.g., Chaney, 2016; Manova, 2013), suggesting that varying capacity in obtaining liquidity, be it through access to external borrowing, equity issuance or internal cash flow, can play an important role in firms' selection into exporting, particularly in innovation-intensive industries.

On the empirical trade front, our paper is related to Bustos (2011) and Lileeva and Trefler (2010) who study the impact of trade liberalizations on productivity and innovation at the plant level and find that export opportunities matter for innovation. Most recently, Autor et al. (2016) analyze the impact of Chinese import competition on innovation by US firms, while Bloom et al. (2016) study the impact of Chinese import competition on measures of innovation of affected European firms. We differ from these studies in two ways: First, we disentangle the impact of globalization into the channel of export opportunities from that of import competition, showing that they differ in important ways. While most papers on trade and innovation have focused on the import competition channel, Aghion, Bergeaud, Lequien and Melitz (2018) and Coelli, Moxnes and Ulltveit-Moe (2017) are among the few studies that have also empirically analyzed the export market channel. Second, to the best of our knowledge, ours is the first paper to link the trend in globalization-induced innovation to shifts in corporate liquidity demand.

Given the connection to corporate liquidity, our paper also builds on a large volume of work in empirical corporate finance that examines patterns and determinants of cash holdings, primarily of public firms in the U.S. (e.g. Bates et al. 2009, Pinkowitz et al. 2016). In Lyandres and Palazzo (2016), cash holdings and innovation are linked through a strategic motive. Cash serves as a commitment device for innovation and in equilibrium, depend on the product market structure and financial constraints that a firm faces. Similar to our paper, Falato, Kadyrzhanova and Sim (2013) also attribute the rise in cash holdings in the U.S. to the increasing importance of intangible assets (measuring the stock of innovation). However, apart from the narrower sample (US Compustat firms), they do not examine the role of globalization in driving the intensity of innovation, a key source for intangible capital accumulation in our model, and instead, relate the need for cash holdings to the low collateralizability of intangible assets. In our model, the motive for cash holdings arises from the nature of investment in innovation, that is, its exposure to cost overrun and moral hazard.[3]

The rest of the paper is organized as follows: section 2 presents some key stylized facts regarding cash holdings, innovation intensity and globalization. Section 3 introduces a

[3]Other motives for cash holdings and corporate saving, less related to our paper's channel, have also found support in the literature: e.g. Foley, Hatzell, Titman and Twite (2007) and Armenter and Hnatkovska (2017) for tax motive, Azar, Kagy and Schmalz (2016) for cost of carry, and Dittmar, Mahrt-Smith and Servaes (2003) for corporate governance motives.

model linking the expansion of export opportunities with the firm's decision to invest in innovation and the implications for cash holdings. Section 4 then outlines the empirical strategy and tests key predictions of the model. Section 5 concludes.

2.2 Stylized facts

The increase in corporate cash holdings is well documented for US corporations, but is in fact a more widespread phenomenon. Figure 2.1 plots the mean and median cash ratio of all firms in each of the five countries in our sample and shows that listed firms in all countries have been holding more and more cash relative to the size of their overall assets at least since the mid 1990's. Interestingly, while the share of cash in total assets has broadly flattened in the U.S. in the mid 2000's, the upward trend continues unabated in the other G7 countries, and only started to pick up in Japan after the global financial crisis. A related macro literature has also documented the concurrent rise in corporate saving in major advanced and emerging economies (e.g. Chen et al. 2017, Dao and Maggi, 2018), suggesting that the rise in cash stock has been financed in part by increased retained earnings, in addition to debt and equity issuance.

At the same time, it is well known that firms have been investing increasingly in intangible assets, instead of physical fixed assets, reflecting the rising importance of knowledge, organizational and other intangible capital as inputs in production (see e.g. Corrado and Hulten, 2010; Alexander and Eberly, 2016). According to some estimates, the stock of intangible has approached that of tangible capital in the U.S. corporate sector during the past decade (Falato et al., 2013). While less is known for other countries other than the U.S., a first look at the data on the share of intangible in overall assets in some of the other G7 countries also reveals a strongly increasing trend (Figure 2.2).

Moreover, the two trends are not unrelated, as becomes evident in the evolution of their cross-sectional distribution. Figure 2.3, which plots the evolution of the median cash ratio for firms in each tercile of innovation intensity in each country, shows that firms with high R&D intensity (measured as R&D spending as a share of total sales) have on average higher cash ratios in all five countries. Also, in country year episodes where the increase in cash ratio has been most pronounced, as e.g. in the U.S. and Germany in the early 2000's, the increase is steepest for the most innovation-intensive firms. The higher level and steeper trend in cash holdings for innovating firms suggest that the decision to innovate and that over the optimal level of cash holdings are closely related. Firms with higher cash ratios also tend to spend more not only on R&D, but also on other activities classified as overhead costs, or Selling, General and Administration (SG&A), comprising advertisement, marketing, training etc. which are not directly linked to current production. Figure 2.4 plots the ratio of SG& A spending (in percent of sales) for different terciles of cash ratios across firms and documents that cash-rich firms tend to spend relatively more on such overhead outlays which are typically aimed at maintaining or boosting long-term profitability.

At the same time as innovation and corporate liquidity demand surged, the world economy experienced what some have dubbed "hyper-globalization" (Subramanian and Kessler, 2013), a period of unprecedented acceleration in cross-border trade, driven primarily by the integration of China and other emerging markets into the world trading system. The pattern is not a mere co-incidence of unrelated time trends, but is corroborated by cross-sectional correlation. When plotting advanced economies' evolution of aggregate cash ratios during 1995-2015 and of their export shares during the same period, we observe a strong positive correlation (Figure 2.5).[4] A one standard deviation increase in the export to GDP ratio is associated with roughly one standard deviation increase in the cash to asset ratio in a given country over time. The prima-facie evidence in Figures 2.3 and 2.5 hence jointly suggest a potentially important relationship between globalization, innovation and cash holdings.

There is evidence that the changing composition of firms in the U.S. has increased the average cash ratio, as younger cohorts of firms launching IPO have been entering the sample with higher cash holdings than incumbent ones in the 1980's to late 1990's (Begenau and Palazzo, 2016). However, this composition effect does not appear to be dominant in the later years and across a broader sample of other industrial countries. Figure 2.6 shows the evolution of median cash ratio by cohorts entering the sample in non-overlapping 5-year periods. While subsequent cohorts entering the sample have been contributing positively to the average cash ratio up until the late 1990's (the 1996-2000 cohorts lying above the previous cohort line in most countries), this relationship fails to hold broadly for subsequent cohorts, with the exception of Japan, where entering cohorts continue to be more cash-rich than incumbent firms. Even in the case of Japan though, the increase in average cash ratio after 2010 is driven also strongly by within-cohort trends. In all other countries, any upward trend in cash-holding post 2000 is predominantly driven by within-cohort trends, suggesting that the composition effect only played a limited role and within-firm dynamics to be of primary importance, particularly in the last decade.

Finally, we also take a more granular look at entering/exiting versus incumbent firms in each year (not only 5-year cohorts) by decomposing the aggregate change in cash to asset ratio into intensive and extensive margins, following Begenau and Palazzo (2016).

[4] Of course export and import shares are highly correlated at the country level, so the positive correlation could be also driven by enhanced import competition. However, when controlling for both export and import shares, we see only a weak and statistically insignificant positive correlation between cash ratio and import shares, while the coefficient on export shares remain significant and of similar magnitude as in the bivariate regression.

$$\Delta \frac{CH_t}{A_t} = \underbrace{\left(\frac{A_t^I}{A_t^I + A_t^{entr}} \frac{CH_t^I}{A_t^I} - \frac{A_{t-1}^I}{A_{t-1}^I + A_{t-1}^{exit}} \frac{CH_{t-1}^I}{A_{t-1}^I} \right)}_{\text{intensive margin}} + \underbrace{\left(\frac{A_t^{entr}}{A_t^I + A_t^{entr}} \frac{CH_t^{entr}}{A_t^{entr}} - \frac{A_{t-1}^I}{A_{t-1}^I + A_{t-1}^{exit}} \frac{CH_{t-1}^{exit}}{A_{t-1}^{exit}} \right)}_{\text{extensive margin}}$$

with the superscript I designating the corresponding variable (cash stock CH and total assets A) of incumbent firms. Figure 2.7 shows the cumulative contribution of the extensive and intensive margin to the total change in aggregate cash ratios. In all countries except for Japan, the intensive margin has been contributing positively to the average cash ratio, whereas the composition of firms has been exerting a negative effect on the aggregate cash ratio, consistent with the cohort-based calculations. In Japan, during the period associated with an increasing overall cash ratio starting from 2010, it has also been the intensive margin, that is, the cash evolution among incumbent firms, that has driven the overall increase.

The relevance of the intensive margin for the rising trend in cash holdings is consistent with the role of within-firm increase in net saving rates (retained earnings) documented in Chen et al. (2017) and Dao and Maggi (2018).

2.3 A model of liquidity demand and export-oriented innovation

Motivated by the preceding stylized facts, in the following, we present the main elements of a model that links the decision on cash holding within a firm to its exposure to trade openness. This model generates an insurance mechanism even in the presence of risk-neutral agents. The demand for liquidity arises from the need to fund cost overruns resulting from long-term investment (such as innovation or other investment in intangible capital) which in turn are spurred by increased globalization. Rising globalization expands export opportunities for the most productive firms and thus boosts returns to being in the top tail of the distribution. This export or market access aspect of globalization, less studied than the import exposure in the literature, thus increases incentives for domestic firms to innovate and move up in the productivity distribution.[5] By doing so, the optimal contract with investors also requires them to hold more cash in order to fund cost overruns and other liquidity shocks occurring before the innovation bears fruit.

[5] A similar mechanism by which exports boosts innovation is presented in Bonfiglioli et al. (2017).

2.3.1 Model set-up

The framework is a 3-period model combining motive for cash holdings as in Holmström and Tirole (1998) and exporter selection with heterogenous firms as in Melitz (2003). In particular, in period **t=0**, an incumbent domestic firm has a given level of productivity ϕ_0 and realizes per period profit $\pi(\phi_0)$, where π is a non-decreasing continuous function in firm productivity which we will further specify below. The firm decides whether to invest in innovation to upgrade its productivity to a higher level $\phi \geq \phi_0$ at fixed cost I. Importantly, we abstract from firm entry and exit in the domestic market.

In the intermediate stage **t=1**, if the firm has invested in innovation, it is exposed to a stochastic liquidity shock in the magnitude ρ which is distributed according to the cdf $F(\rho)$ on the support $[0, \infty)$. This liquidity shock can be seen as a cost over-run or a stochastic re-investment need. If the firm does not pay ρ, its investment is lost and it reverts to its status quo. If it pays ρ, it survives until the next period. We assume that when the liquidity shock hits, the firm cannot rely on borrowing or raising capital sufficiently fast to entirely cover the cost overrun. Therefore, the funds to cover the liquidity shock need to be hoarded as cash in advance.[6]

Upon surviving the liquidity shock, the firm reaps the benefit of its innovation investment in period **t=2** by drawing a new productivity from a Pareto distribution with density function $g(\phi)$ over the support $[\phi_0, \infty)$, and shape parameter κ which pins down the dispersion of the distribution. A lower κ represents a thicker upper-tail distribution and hence a higher probability of drawing a high productivity.

After drawing the new productivity, the firm has an opportunity to become an exporter. Exporting requires paying fixed costs f_X and variable (iceberg) costs $\tau > 1$ as in Melitz (2003). Therefore, if the firm's productivity draw is above a cutoff value, it will serve both the domestic and foreign markets, whereas if it is below the cutoff, it continues to serve the domestic market only, but still operates at higher productivity $\phi \geq \phi_0$ and realizes higher profit relative to not innovating.

The timing of the events are illustrated in Figure 2.8. Two assumptions of the model are key for our main results. First, the timing of the innovation investment under liquidity risk and the realization of its payoff: if returns to innovation are realized immediately at the time of investment, i.e. firms draw their new productivity in $t = 0$, then the subsequent liquidity shock would act as an exogenous exit probability as in Bustos (2011) and no cash-in-advance motive would materialize. Firms which draw a liquidity shock exceeding its new productivity would abandon the new technology, while those drawing a smaller liquidity shock would absorb it with their higher profits. Second, the financial

[6] Later, in the Appendix, we relax this simplifying assumption and endogenize the firm's financing decision as a solution of the optimal contract in the presence of information asymmetry between the firm and outside investors that gives rise to moral hazard. In short, firms will always *choose* to hold cash in advance to insure against liquidity shocks. This is because moral hazard will prevent the firm from being able to commit the full net present value of the innovation to investors in certain instances, under which the firm would then forego positive investment opportunities were it to rely only on borrowing at the time of the liquidity shock.

constraint is essential, too. As argued above and detailed in the Appendix, without financing constraint or moral hazard, firms would just issue equity or borrow the necessary amount to cover the liquidity shock once it hits, even if the timing assumption holds, and not hold more cash in advance.

2.3.2 Model solution

We solve the model backwards by first considering the exporter selection stage $t = 2$. As in Melitz (2003), we assume consumers in both the domestic and export markets have the same CES utility over a continuum of substitutable goods with elasticity of substitution $\sigma > 1$, and producers (firms) being monopolistically competitive. Conditional on drawing productivity ϕ, the firm's profit as a function of its new productivity is given by its profit in domestic and export markets (see derivation in Appendix):

$$\pi(\phi) = \pi^D(\phi) + \pi^X(\phi) = M\phi^{\sigma-1} + M^X \left(\frac{\phi}{\tau}\right)^{\sigma-1} - f_X, \tag{2.1}$$

with M, M^X being composite terms reflecting total demand in domestic and export markets, taken as given by the firm, and f_X and τ being the fixed and variable cost of exporting as introduced above. Since profits are increasing in ϕ, the firm will only export if its productivity draw is above a cutoff ϕ_X^* which is pinned down by the zero profit condition for exporting:

$$\phi_X^* = \tau \left(\frac{f_x}{M^X}\right)^{\frac{1}{\sigma-1}} \tag{2.2}$$

Intuitively, the exporting cutoff is lower with lower trade costs and larger export markets. The ex-ante expected profit is therefore:

$$E(\pi) = \int_{\phi_0}^{\infty} M\phi^{\sigma-1} g(\phi) d\phi + \int_{\phi_X^*}^{\infty} \left[M^X \left(\frac{\phi}{\tau}\right)^{\sigma-1} - f_X\right] g(\phi) d\phi, \tag{2.3}$$

where $g(\phi)$ is the density function of the new (post-innovation) productivity distribution with shape parameter κ. Applying the properties and parameters of the Pareto distribution, defining $\xi = \sigma - 1$, we can solve for expected profit conditional on innovating to be:

$$E(\pi) = \frac{M\kappa}{\kappa - \xi}\phi_0^{\xi} + \frac{\kappa f_x}{\kappa - \xi}\phi_X^*(f_x, \tau, M^x)^{-\kappa}\phi_0^{\kappa}, \tag{2.4}$$

and the return from innovation is therefore:

$$E(R(\phi_0)) = E(\pi) - \pi_0 = \frac{M\xi}{\kappa - \xi}\phi_0^{\xi} + \frac{\kappa f_x}{\kappa - \xi}\phi_X^*(f_x, \tau, M^x)^{-\kappa}\phi_0^{\kappa}, \tag{2.5}$$

where we have $\frac{\partial E(\pi)}{\partial \tau} < 0$ and $\frac{\partial E(\pi)}{\partial M^x} > 0$. With lower trade costs and/or larger export markets, the profit for each exporter with given productivity is higher, at the same time as the probability of becoming an exporter is higher, both contributing to higher ex-ante expected profits. At the same time, higher initial productivity ϕ_0 raises expected profit conditional on innovating, as higher ϕ_0, being the lower bound for the new productivity draw, leads on average to a higher level of post-innovation productivity and hence results in higher expected profit in domestic as well as export markets.

Now moving to $t = 1$, conditional on being hit by a liquidity shock ρ, it immediately follows that the firm should continue whenever ρ is not too high so as to maintain a positive net payoff from the innovation. Denoting this threshold by ρ^1, we can derive its value from the first order condition of:

$$max_{\rho^1} NPV = max_{\rho^1} \int_0^{\rho^1} [E(R(\phi)) - \rho] f(\rho) d\rho - I, \tag{2.6}$$

which yields $\rho^1 = E(R(\phi_0))$, that is, the firm maximizes the net present value (NPV) of the innovation project by covering the liquidity shock/cost overrun as long as it does not exceed the expected profit from continuing the innovation. This first-best threshold ρ^1 then is the cash amount the firm needs to hold in $t = 0$.

In $t = 0$, if the net present value of the innovation project is positive (which, for given I, effectively requires a minimum productivity level for innovating firms), the firm will want to innovate and pay the upfront amount I plus hold the cash amount ρ^1 to insure against the liquidity shock in $t = 1$.

We establish the following main results.

Result 1 *Only firms above a minimum productivity cutoff will innovate. Innovating firms hold more cash than non-innovating firms. Innovating firms with higher initial productivity hold more cash.*

From equation (2.6) above, we can express the maximized NPV for a firm with given initial productivity ϕ_0 as

$$MNPV(\phi_0) = \int_0^{\rho^1(\phi_0)} [E(R(\phi_0)) - \rho] f(\rho) d\rho - I, \tag{2.7}$$

Only firms with positive expected MNPV from innovating will do so. In other words, only firms with initial productivity above the cutoff level ϕ_0^1 will choose to innovate, where the cutoff level is obtained from the break-even condition $MNPV(\phi_0^1) = 0$. These firms will pay the upfront cost I and hoard the cash amount ρ^1 to cover subsequent liquidity risk. All else equal, therefore, their cash holdings will be higher by the amount ρ^1 compared to non-innovating firms. Moreover, from equation (2.5), we know:

$$\frac{\partial \rho^1(\phi_0)}{\partial \phi_0} = \frac{\partial E(R(\phi_0))}{\partial \phi_0} = \frac{M\xi^2}{\kappa - \xi} \phi_0^{\xi-1} + \frac{\kappa^2 f_x}{\kappa - \xi} \phi_X^*(f_x, \tau)^{-\kappa} \phi_0^{\kappa-1} > 0, \tag{2.8}$$

so that the innovation-accompanying amount of cash holdings increases with the ex-ante productivity of the firm. This crucial result distinguishes our motive of cash holdings from others in the literature where demand for cash is a result of intangible capital shrinking the firm's collateral base and external financing capacity (see e.g. Falato et al. 2013). Unlike the collateral channel that generates a stronger motive of cash holdings for smaller firms facing more financial frictions, the innovation channel in our model, encompassing investment in intangible capital, leads to a higher level of cash holdings for *larger*, more productive firms. This is because more productive firms expect more payoff from productivity enhancing innovation and hence are willing to absorb larger liquidity shocks in the interim to keep their "skin in the game".

Result 2 *Conditional on being an innovating firm, globalization in terms of lower trade costs* τ *and/or expanded foreign market size* M^X *increases the level of the firm's cash holdings, that is* $\frac{\partial \rho^1}{\partial \tau} < 0, \frac{\partial \rho^1}{\partial M^X} > 0$*. Moreover, more productive firms increase their cash holdings more in response to the same shock than less productive ones.*

This result follows from taking the derivative of ρ^1 with respect to M^X, that is:

$$\frac{\partial \rho^1}{\partial M^X} = \frac{\partial E(R)}{\partial M^X} = \Omega(\tau, M^X, f_X, \kappa, \sigma)\phi_0^{\kappa} > 0, \tag{2.9}$$

where $\Omega(.) > 0$ is a composite function of underlying parameters of the model taking on positive values (and similarly for a reduction in τ). A positive export shock increases the returns from innovation and hence makes firms willing to absorb larger liquidity shocks, therefore raising the optimal cash holdings of any firm above the innovation productivity cutoff. In addition, as $\kappa > 0$, it follows that this increase in cash holdings from a positive export shock is increasing in the underlying productivity level ϕ_0. Intuitively, a more productive firm is more able to translate the better export opportunity into higher profits, and thus will hold more cash to withstand larger liquidity shocks so as to reap these profits eventually.

Result 3 *Globalization in terms of lower trade costs* τ *and/or expanded foreign market size* M^X *reduces the productivity cutoff for innovation and thus, for a given distribution of initial productivity across firms, increases innovation activity and the average cash holdings among incumbent firms in the industry.*

As derived in result 1, the minimum productivity cutoff for innovating firms is given by the break-even condition $MNPV(\phi_0^1) = 0$. At the same time, we know that a positive export shock raises the $MNPV$ for all values of ϕ_0, as per envelope theorem, we have $\frac{\partial MNPV}{\partial M^X} = F(\rho^1)\frac{\partial E(R)}{\partial M^X} > 0$. It immediately follows that for given innovation costs I, a positive globalization shock lowers the minimum productivity cutoff for firms to innovate. In other words, a larger M_X and/or lower τ shift down the inverse function $MNPV^{-1}(.)$ and reduce $\phi_0^1 = MNPV^{-1}(0)$ to the lower value ϕ_0^2.

All three results regarding the schedule of optimal cash holdings as a function of the initial productivity, the set of innovating firms, and the shifted curve triggered by more trade openness (through lower trade costs and/or larger markets) are depicted in Figure 2.9. As derived above, the schedule of optimal cash holdings is a convex positive function of the underlying productivity level above the minimum productivity cutoff ϕ_0^1. A trade liberalization that lowers trade cost τ or expands access to foreign markets M_X shifts the schedule inward and for any given level of ϕ_0, steepens the slope of the cash holdings schedule. As a result, the increase in cash holdings is disproportionately larger for more productive firms, and zero for firms below the cutoff. Moreover, for any given productivity distribution, export liberalization also expands the set of innovating firms by reducing the cutoff.[7]

It is well known that opening to trade tends to benefit large, productive exporting firms, similar to our findings about the productivity threshold in results 1 and 3. Atkeson and Burstein (2010), for example, show analytically how a reduction in trade costs increases investment in process innovation for large firms. In their model firms can invest to increase the probability of an incremental increase in their productivity. The novelty of our results is to study the implications of a reduction in trade costs for firm liqudity.

2.3.3 Testable implications

The main testable predictions of the model can be summarized as the following:

- For the within-firm variation in cash holdings, Result 1 and Result 2 predict that a firm's cash holdings should increase with export opportunities only if the firm has high enough underlying productivity. Using different proxies for a firm's productivity, we should see that the marginal impact of trade openness on cash holdings is stronger for more productive firms. Moreover, the differential of this marginal impact should be most pronounced when comparing firms with the highest and lowest productivity levels, while comparison with firms of intermediate productivity is less unambiguous in the extended version of the model (see Figure 2.15). Importantly, this differential prediction that export opportunities affect firms with higher productivity more also allows us to discriminate between our channel and those relying on innovation interacting with financial constraints such as Falato et al. (2013), where innovation raises cash holdings more in smaller/less productive firms, as they face more external financing constraint.[8]

[7] In the Appendix, we relax the financing constraint in $t = 1$ and allow the firm to borrow/raise equity at the time of the liquidity shock, but subject to well-known informational asymmetry that gives rise to moral hazard. We show that all 3 main results still go through, in particular, firms still choose to hold the cash in advance as they cannot commit to the full NPV of the innovation project due to moral hazard.

[8] In other words, in our model, the less productive/typically smaller a firm is, the lower are its expected returns from innovation and the less cash it will be *willing* to hold. In contrast, in alternative models, the more constrained a firm is by lack of external financing capacity, the more cash it *must* hold to self-insure against productivity shocks.

- Result 2 predicts that, if the firm has high enough productivity, the increase in cash holdings facilitates more innovation activity by making firms more able to absorb liquidity shocks in the interim. Measured spending on innovation (equal $I + \int_0^{\rho^1} \rho f(\rho) d\rho$ in the model) will therefore also increase with expanding export opportunities.[9] Similar to the result for cash, this positive effect should be stronger for larger (or more productive/more profitable/export-oriented) firms.

- At the industry-level within a country, Result 3 implies that cash holdings increases on average in an industry when its export opportunities increase. In line with the model, we should also see the average industry-wide R&D spending, a measure of innovation intensity at the industry-level, increase at the same time. However, the average industry-level outcome may be small and hard to be identified due to the heterogeneity in the impact of globalization across firms with varying level of productivity. Moreover, the industry result relies on the prediction that improved market access also allows new firms to become innovators (as the asset threshold falls). However, this extensive margin of innovation is not possible to measure in the R&D data, as missing entries for R&D spending can reflect either a non-reporting of actual spending or zero spending on R&D.[10] We therefore focus on the intensive margin of innovation and associated cash holdings (Results 1 and 2) in the empirical analysis below.

2.4 Empirical Analysis

2.4.1 Data

We use Thomson Reuter Worldscope data spanning the period 1995-2014 for five major industrial countries where coverage of publicly listed firms is among the most comprehensive: the U.S., UK, Germany, Japan, and France. Following the literature, excluded are firms with: negative equity, negative sales and missing value for total assets, as well as firms in the utilities and financial sector (sic 6000-6799, sic 4900-4999, sic 9000-9999, sic 1800-1999).

Table 2.2 summarizes the median of some key variables for each country in the sample. Overall, firms hold about 10 percent of total assets in cash and short-term investment (cash-like instruments), with Japanese firms having the highest cash ratio of 15 percent for the median firm and being on average the largest in terms of asset size. Among firms that have positive R&D spending, US firms are the most active in terms of investing in innovation, spending on average over twice as much on R&D as a share of their revenues than firms in other countries, while they are also the least likely to pay out dividends.[11]

[9] Note that this prediction applies to spending on innovation, not necessarily its outcome or quality.

[10] This is a well-known limitation of firm-level R&D obtained from balance sheet and financial statements data, see e.g. Lev and Radhakrishnan (2005).

[11] While we have almost 200,000 firm-year observations over which these summary statistics are computed,

Although the dataset contains consolidated accounts of mostly publicly listed firms, evidence in Dao and Maggi (2018) confirms that the combined cash holdings and net lending rates of these large firms, when added up, track well the aggregate evolution of corresponding variables from official flow of funds and sectoral national accounts data. This finding on aggregate representativeness is consistent with other studies focusing exclusively on the U.S. corporate sector, which also established that the corporate net lending as well as cash holdings is extremely concentrated among large firms (see Armenter, 2012 and references therein). Understanding drivers of cash holdings and saving by listed firms can therefore shed light on forces that drive the evolution of overall private saving (to which the corporate sector contributes substantially), real interest rates and the current account.

Worldscope provides two main four-digit-level standard industry classifications (SIC) for each firm, accompanied by the amount of sales of each category. Using an initial year's product segment sales shares, we can construct each firm's exposure to export opportunities and import competition by combining this firm-level data with industry-level trade and tariff data. The bilateral trade data, sector output data, and MFN tariff data come from the UN Comtrade database, World Input Output Database (WIOD), and TRAINS database, respectively, all of which are then matched to the SIC code of each firm in an initial year to derive sector- or firm-specific weighted average exposure to export and import shocks (more details below).

Figure 2.10 illustrates a rapidly growing role of China in trade with advanced economies in our sample. It also highlights substantial variation across countries and industries, providing a source of identification for our econometric analysis below. Similarly, Figure 2.11 describes the extent of tariff liberalization in our sample economies and their trading partners. It is worth noting that import tariff liberalization has been stagnant over the last two decades in our sample countries, mainly because their tariff rates had already reached low levels by the mid 1990's. In contrast, their trading partners, many of them emerging market economies, whose tariff rates were relatively high, have undergone substantial tariff liberalization over the same period. In this regard, as far as tariff rates are concerned, firms in our sample appear to have experienced not so much import shocks as positive export shocks. This fact underscores the importance to look at both the export and import margins when analyzing the effect of trade.

Our empirical strategy essentially relies on a difference-in-difference identification of the heterogeneous effect of export shocks across firms with differential initial productivity level ϕ_0. In a multi-factor production environment, the variable ϕ_0 should correspond to firm-level total factor productivity (TFP). Crucial elements for computing firm-level TFP are however not available in our dataset (such as intermediate inputs, prices etc). Thus, we will have to rely on simple proxies following the literature such as size, labor

in the following, the sample is greatly reduced when we seek to compute a firm-level or sector-level measure of exposure to export and import.

productivity, export intensity, or profitability.[12]

Another important aspect of our model is the firm's decision to engage in long-term investment in innovation. We understand innovation here as any activity that requires long-term financial commitment with uncertain outcomes, and exposes the firm to liquidity risk in the interim. R&D is one category of such innovation activities, and evidence exists that firms indeed use cash holdings to smooth R&D expenditure, which is costly to adjust, in response to financing shocks (Brown and Petersen, 2011). But similar risk applies to other activity of the firm that increases its intangible capital stock, in particular investment in its human, organizational and social capital (see Lev and Radhakrishnan, 2005; Eisfeldt and Papanikolaou, 2013). The reason is because spending on such activities as internal training, brand development, development of distribution networks etc. require steady and long-term outlays, increasing the share of quasi-fixed costs and decoupling the firm's revenues from its operating expenditure, hence increasing its exposure to liquidity shortage (see Srivastava and Tse, 2016). However, we do not have data on such activities by firms. The closest measure encompassing such intangible capital enhancing spending are spending on so-called SG&A (selling, general and administration costs), which however also contain non-intangible enhancing expenses such as social security taxes, pension costs, and other overhead costs. We therefore consider both R&D and SG&A spending as our measure of innovation activity when investigating the underlying channel through which globalization leads to an increase in cash holdings.

2.4.2 Empirical Strategy

The main testable hypothesis from the model in this paper is that rising globalization, particularly in terms of expanded export opportunities, would lead to an increase in cash holdings, and particularly more so for innovating firm with higher productivity. Moreover, the model suggests that it occurs through boosting incentive for innovation, resulting in an increase in innovation spending, more so in firms with higher initial productivity.

Accordingly, at the firm-level, we use the following baseline specification to test the main hypotheses:

$$Y_{ijct} = \beta^{exp} SHOCK^{exp}_{jct} + \beta^{imp} SHOCK^{imp}_{jct} + \Theta Z_{ijct} + FE + \varepsilon_{ijct},$$

where Y_{ijct} is the dependent variable of interest, primarily the ratio of cash holdings to total assets in log for firm i in two-digit-level sector j and country c at year t. $SHOCK^{exp}_{jct}$ captures the country-sector-year-level potential export opportunities that could stem

[12]Modern heterogeneous-firms trade models center on the productivity sorting of exporter status: that is, the most productive firms become exporters, as has been strongly supported in the empirical trade literature. Moreover, it has been well established that larger firms are more likely to be exporters (Bernard, Jensen, Redding, and Schott, 2007; Bernard, Jensen, and Schott, 2009). Given the likely noisiness in TFP estimates, researchers have relied on various proxies for the productivity level, ranging from firm size, labor productivity, export intensity, to measures of profitability (e.g., Verhoogen, 2008).

from, for instance, improved foreign market access or increased demand abroad. Likewise, $SHOCK_{jct}^{imp}$ denotes the degree of country-sector-year-level import competition that domestic firms face. As such, export and import shocks are separately estimated. Z_{ijct} is a set of other relevant control variables such as a firm's total sales volume, operating cash flow, etc. The baseline regression includes firm fixed effects to explore within-firm variation over time in response to changing degrees of globalization. In addition, country-year fixed effects would absorb any other macroeconomic factors that could affect a firm's cash holding decision.

As spelled out above, the model predicts that the effect of globalization should be more pronounced for firms with higher initial productivity, as they are more likely to undertake innovation-related investment (due to selection into innovation) and more able to translate the better export opportunity into higher profits (due to the post-innovation productivity distribution). This prediction can be tested by including additional interaction terms to capture heterogeneous responses along different levels of productivity proxied by, for instance, size (measured by total assets), productivity (measured by labor productivity), export intensity (measured by the share of foreign sales), or profitability (measured by net income per employee). Specifically, we assign each firm a tercile dummy variable encoding its relative position in the distribution of the respective productivity proxy in a given country and year. The corresponding specification can then be expressed as:

$$Y_{ijct} = \sum\nolimits_{k=exp,imp} \left[\beta^k SHOCK_{jct}^k + \sum\nolimits_{l=2,3} \beta_l^k SHOCK_{jct}^k * I_{ijct,l} \right] + \Theta Z_{ijct} + FE + \varepsilon_{ijct},$$

where $I_{ijct,l}$ is a tercile dummy variable, whose stand-alone level is also included in Z_{ijct}.

A typical empirical challenge in identifying the causal effect of globalization on firm-level decisions is likely to prevail in this setting, not least because our sample is composed of publicly listed firms, some of which are large enough to influence potential globalization measures. In an effort to alleviate such endogeneity concerns, among several possible candidate variables for $SHOCK_{jct}^{exp,imp}$, we employ measures of exports to, and imports from, China—both scaled by the two-digit country-sector-level output—as a measure for export opportunities and import competition, respectively:

$$SHOCK_{jct}^{exp} = \left(\frac{\text{Total Exports to China}}{\text{Total Output}} \right)_{jct},$$

and

$$SHOCK_{jct}^{imp} = \left(\frac{\text{Total Imports from China}}{\text{Total Output}} \right)_{jct}.$$

To the extent that much of the recent rise in trade with China is driven by supply-side and demand-side shocks from China—productivity shocks for China's exports and unilateral trade liberalization for China's imports—, these measures are expected to embody exogenous shocks from the perspective of a firm in any given G7 partner country.

Still, however, we acknowledge that such measures are not entirely immune to potential endogeneity biases. We thus follow Autor et al. (2013) and Autor et al. (2016) to further instrument them with the corresponding average values of other advanced economies. This instrumental variable approach allows us to extract China-made exogenous shocks in each industry, which in turn underlie the rising role of China in global trade.[13] Such China-specific shocks common to all third partner countries should therefore be strongly correlated with the change in export opportunities and import competition in a given partner country, but would not be directly related to a firm's cash holdings and innovation spending once their overall performance and other macroeconomic specific shocks are controlled for.

Past evidence, as discussed in detail in Autor et al. (2013), tends to lend support for the validity of our identification strategy in that demand and/or technology shocks common to major advanced economies played only a minor role in explaining the recent surge in China's trade. Nevertheless, caution is warranted in interpreting the estimated coefficients below, in case our instrumental variables are still contaminated by any remaining correlated demand and supply shocks across countries, such as sector-year-level common trend in technological growth.[14] As robustness checks, we thus also consider alternative firm-level trade shock measures, thereby ensuring sufficient variation across firms even with additional sector-year fixed effects to absorb any such concerns.[15]

The first alternative measure is constructed as the weighted average of four-digit country-sector-level shocks:

$$SHOCK_{ijct}^{exp} = \sum\nolimits_{j'} \omega_{ij'c} \left(\frac{\text{Total Exports to China}}{\text{Total Exports}} \right)_{j'ct},$$

for exports, and

$$SHOCK_{ijct}^{imp} = \sum\nolimits_{j'} \omega_{ij'c} \left(\frac{\text{Total Imports from China}}{\text{Total Imports}} \right)_{j'ct},$$

for imports, respectively, where the share of exports to (imports from) China in total exports (imports) is used as a four-digit country-sector-level export (import) shock measure and the weights are calculated using the initial year's sales share of the primary and

[13]In essence, our import shock measure and its instrumental variable exactly follow Autor et al. (2013) and Autor et al. (2016). We apply their idea similarly to construct export shock measures and instrumental variables as in Ahn and Duval (2018), which is in turn comparable to the export demand shock measure developed in Mayer, Melitz, and Ottaviano (2016).

[14]In principle, we could include sector-year fixed effects in the baseline specification. However, our instrumental variable approach aims to extract sector-year-level common exogenous trade shocks induced by China, which would leave little variation across countries once sector-year fixed effects are included.

[15]The baseline measure is defined at two-digit country-sector level because total output data from World Input Output Database (WIOD) is available at two-digit sector level. Since most firms in our sample report two distinct primary and secondary four-digit sectors that belong to a single two-digit sector, it is not feasible to construct firm-level trade shock variables using two-digit country-sector-level measures.

secondary four-digit SIC codes, j', for each firm. That is, the country-sector level export/import exposure to China is converted to a firm-level one using weights $\omega_{ij'c}$, which corresponds to the respective share of a given firm's sales in each four-digit sector in the initial year. As above, we further consider instrumental variables for 2SLS estimation by taking the corresponding average values from other advanced economies while keeping the firm-level weight.

The second alternative measure is constructed by replacing China-based trade shock measures with tariff-based measures:

$$MFN_{ijct}^{k} = \sum\nolimits_{j'} \omega_{ij'c} \left(\tau^{k}\right)_{j'ct-1}$$

for $k = \{exp, imp\}$, where the weight $\omega_{ij'c}$ is defined as above, while $\tau_{cj'}^{imp}$ denotes country $c's$ most favored nation (MFN) tariff rate imposed on imported goods from industry j', and $\tau_{cj'}^{exp}$ is a weighted average of MFN tariff rates that a country $c's$ exporters in industry j' would face in their destination countries.[16]

2.4.3 Estimation Results

Baseline estimation results Table 2.1 and Table 2.3 present firm-level estimation results from our baseline specification using OLS and 2SLS, respectively, where the dependent variable is cash-to-asset ratio in log (multiplied by 100 for ease of interpretation). Column 1 reports estimation results from the baseline specification without any interaction terms, while columns 2, 3, and 4 summarize estimation results from the augmented specification that includes interaction terms with tercile dummy variables based on total asset size.

A first look at the OLS estimation results in Table 2.1 suggests a significant within-firm increase in cash holdings, on average, in response to expanded export opportunities (column 1). As we add interaction terms with tercile dummy variables, no differential effects across firms are found (column 2). However, as country-year fixed effects are further added to control for macroeconomic shocks, the effect turns out to be concentrated among bigger firms (column 3). The results continue to hold after taking into account the effect of import competition. Interestingly, the export channel tends to dominate the import channel in that the point estimate on the former is about 10 times bigger than that of the latter (column 4).

Turning to Table 2.3 for 2SLS estimation results whereby the country-sector-level trade shock measures are instrumented by the average values in the other advanced economies, qualitatively identical results to those from OLS estimation are found. The first stage regression result in the bottom panel supports the strength of the instrumental

[16]The weight used in calculating export MFN tariff rate is based on the share of exports by destination countries in each four-digit sector in the initial year.

variable—the substantial predictive power of instrumental variables from the peer country group's trade with China for a given country's export shock is confirmed. The second stage regression results in the upper panel further reveals that the coefficient estimates on the export shock variable from 2SLS estimator tend to be significantly greater in absolute terms than those from OLS estimator, suggesting that our instrumental variable strategy could partly correct for attenuation bias—due to measurement errors particularly in export shock variables—as well as omitted variable bias that would push the relationship negatively—reflecting for instance forces that discourage investment of domestic firms for precautionary reasons and hence, reduce their exports to China but boost their cash holdings.

The size of the estimated coefficient in column (4) implies that, conditional on all other macroeconomic and firm-level factors affecting cash holdings proportionately across firms, a 1 percentage point increase in export opportunities to China raises cash-to-asset ratio by around 8 percent more for largest firms compared to average firms in that country and year, whereas smallest firms actually reduce cash-to-asset ratio by around 5 percent relative to average firms in a given country-year. A simple back-of-the-envelope calculation suggests that globalization-led growth in export opportunities explains around 25 percent of the differential growth in cash holdings between bottom and top tercile firms over the period 2000-2011 for US firms, with the magnitude ranging from 10 percent for French firms to 86 percent for German firms. On the other hand, the import channel yields much smaller and nosier estimates, possibly reflecting offsetting forces of increased foreign competition on innovation activity such as the 'Schumpeterian' force versus the 'escape competition' force proposed in Aghion, Bloom, Blundell, Griffith and Howitt (2005).

Figure 2.12 illustrates this differential effect stemming from the export channel (as reported in column 2 in Table 2.3), by plotting the reduced-form correlation between cash ratio and the China export shock for large and small firms, conditional on other explanatory variables in the baseline regression. While the positive correlation is also found for firms in the bottom tercile of the asset size distribution, the slope is steepest for the top tercile firms. To the extent that firm size is a valid proxy for firm-level productivity, such heterogeneity in the degree of the export channel on cash holdings is consistent with the model prediction.[17] Since the regressions control for firm fixed effects as well as sales and operating cash flows, we stress that the impact on cash holdings is not mechanically driven by increased profitability.

Alternative trade shock measures One potential concern about our baseline estimation strategy that exploits sector-level trade shocks stemming from China is that trade shock measures might be contaminated by other types of sector-year-level variation such

[17]Similar differences in slopes are also found using the other proxies for firm productivity (average labor productivity, foreign sales share, and profitability).

as common technological growth trends. To check robustness of our baseline results to such concerns, we first tweak the underlying original trade shock measure (that was scaled by total output) to one scaled by total exports in each country-sector-year. This basically allows us to construct trade shock measures at the four-digit sector level, which in turn enables us to construct firm-level trade shocks by taking a weighted average across the two main four-digit sectors for each firm, with weights being the firm's sales share in its two main product segments. This alternative trade shock measures the role of China in each country-sector's overall trade, rather than overall production and absorption as in the baseline. With these more granular trade shock measures now varying across firms in a given country-sector, additional sector-year fixed effects can be added to control for common sector-year shocks across countries, effectively isolating trade shocks from other sources of sector-level shocks. Table 2.4 confirms that results are qualitatively identical to the baseline estimation results.

Alternatively, we also compute trade shock measures based on tariff rates at the country-industry level. In particular, we compute a firm-specific measure of export tariff by using the lagged MFN tariff rate for each product (averaged across countries using trade weights at the beginning of the sample period), which is then weighted across products using the firm's sales share in its two main product segments defined at the four-digit level. A change in MFN tariffs in trading partner countries is arguably exogenous to an individual firm incorporated in the exporting country and hence presents a useful robustness check of our main results. To control for the effect of increased import competition resulting from domestic tariff liberalization, we also compute a corresponding measure using the import MFN tariff in each product category, weighted in a similar manner.

Estimation results for cash holdings using these alternative MFN tariff-based trade shocks are summarized in Table 2.5. Consistent with the baseline results using the China trade shock, we find that a decline in export tariffs faced by firms is associated with higher cash holdings for firms in the top tercile of the asset size in each country, but lower cash holdings for firms in the bottom tercile, both relative to average firms in a given country-year. Once again, the impact is stronger through the export expansion rather than the import competition channel.

Confirming the innovation channel Next, we turn to testing the underlying mechanism of the model: firms raise cash holdings because of an increased incentive for R&D and intangible investment in response to globalization shocks. This implies that the effect of globalization on cash holdings should be observed only among firms that do invest in innovation activity, which can be tested by checking the baseline estimation results for innovative and non-innovative firms separately. We define innovative firms as those who have ever spent on R&D, and non-innovative firms as those who have never spent on R&D over the sample period. Column 1 in Table 2.6 reports the estimation results for innovative firms which are somewhat stronger than the baseline estimation results reported in column 4 in Table 2.3. On the other hand, column 2 in Table 2.6 shows that there is no significant effects from export or import shocks across all types of firms, which can be interpreted as a placebo test.[18]

Alternatively, noting that our model implies that an increase in cash holdings would be eventually translated to an increase in R&D spending, we can check the prediction by replacing the dependent variable in the baseline specification above with R&D spending-to-sales ratio in log (multiplied by 100 for ease of interpretation). Column 3 in Table 2.6 presents the estimation results from our baseline specification using 2SLS estimator, which confirm the model-implied mechanism: the estimated heterogeneity of the export effect on innovation spending across firms mirrors the model's prediction for cash holdings. We find the presence of significant and sizable export channel effects particularly for bigger firms, whereas smallest firms actually reduce their R&D investment relative to average firms in a given country-sector in response to positive export shocks.

In fact, our model's mechanism should apply to any activity by the firm that enhances its productivity in the long run but exposes it to higher liquidity risk in the short to medium run. Although R&D is important category of such of innovation spending, it has been argued that a range of other types of expenditure represent investment in intangible organizational, social, and human capital (see Eisfeldt and Papanikolaou, 2013). These are for example spending in employee training, marketing, advertising, branding, IT upgrading etc., which tend to enhance profits in the long run, but due to their nature of being quasi-fixed cost, in the short-run introduce more disconnect between cost and revenues and thus, heighten liquidity risk. Data from income statement contain such expenditure (in addition to R&D spending) in the variable SG&A (selling, general and administration), and has often been used in the literature to construct flows of investment in intangible capital (Falato et al. 2013, 2014; Eisfeldt and Papanikolaou, 2013), although these may also capture other kinds of non-innovation related spending such as contribution to employee's social security funds. Column 4 in Table 2.6 reports the baseline regression results using the share of SG&A spending (in percent of sales) as the dependent variable (multiplied by 100 for ease of interpretation), confirming the main result of positive and stronger effect of export shocks on broader innovation spending for bigger firms.

Confirming the liquidity risk channel We have shown that larger/more productive firms tend to increase cash holdings and spending on innovation and other quasi-overhead outlays when experiencing a positive export shock, consistent with our model's prediction. One final missing link is whether such firms indeed face increased liquidity risk subsequent to incurring such innovation spending to boost productivity, that is, in period t=1 of the

[18]Our main findings broadly hold whether we set missing R&D spending to zero or not.

model. We test this prediction in our empirical framework by estimating the differential effect of export shocks on the forward-looking volatility of cash flow from operations. That is, for each firm and year, we compute the standard deviation of cash flow from operation (scaled by assets) over the subsequent 4 years. The results are summarized in Table 2.8.

Indeed, as shown in column 1, larger firms experience significantly higher cash flow volatility (and thus, liquidity risk) than smaller firms when faced with the same export shock. Interestingly, columns 2-4 further show that this positive volatility differential in response to export shocks is driven only by those firms who also have a relatively high level of spending on innovation activities (that is, firms with relatively high spending on SG&A as a share of sales). This is exactly what our model predicts, as increased overhead spending on activities associated with augmenting intangible capital drives the need for higher precautionary cash holdings. For the separately identified import shock, the effect is exactly opposite. That is, larger firms hit with the same import competition shock tend to experience less cash flow volatility going forward, consistent with the view that larger firms are more able to absorb negative domestic sale shocks from more intense import competition due to their ability to diversify and substitute across domestic and foreign markets (see e.g. Vannoorenberghe, 2012). The result that only large firms with high share of spending on intangible/innovation activities experience increased cash flow volatility after an export shock suggests that it is not due to increased uncertainty from export exposure *per se* (independent from innovation) that drive their need for cash holding.

Alternative firm-level proxies Our baseline specification used firm size (total assets) as a proxy for firm-level productivity. Alternatively, we could consider labor productivity (sales per employee), export intensity (foreign sales in percent of total sales), or profitability (net income per employee) as alternative proxies for firm-level productivity.[19] Table 2.9 summarizes the baseline regression using this set of alternative proxies for firm-level productivity. The overall results are found robust across different types of firm-level productivity measures.

Overall, our results have shown that firms respond to globalization shocks—especially those associated with expanding export opportunities—by raising cash holdings, and that this effect is consistent with stronger incentives for R&D and intangible investment. Moreover, our results confirm that such patterns tend to hold more strongly for more productive firms, whether proxied by size, labor productivity, export intensity, or profitability. All of these findings are consistent with the model's prediction that incomplete pledgeability of returns to innovation, coupled with interim liquidity risk, creates demand for cash. The growing incentive to invest in innovation and other intangible capital as-

[19] Unfortunately, our dataset is not well suited to estimate firm-level total factor productivity (TFP) due to incomplete data coverage on intermediate inputs.

sociated with growing globalization can therefore explain part of the recent increase in corporate cash holdings worldwide. Next, we turn to checking the robustness of our main findings to other potential motives for cash holdings.

Controlling for other motives Noting that previous studies mostly focused on US firms where tax motive is proposed to be a major determinant of an increase in cash holdings (Foley et al. 2007), we check the possibility that our main findings are somehow driven by tax motives. Specifically, as an attempt to disentangle the tax motive from the globalization channel we propose in the model, we control directly for the effective tax rate (ETR) for a given firm, computed as the ratio of total taxes (both domestic and foreign) paid divided by pre-tax book income. This measure of ETR has been commonly used in the literature to measure the tax burden of a firm at a consolidated basis (e.g., Markle and Shackelford, 2012). The identifying assumption is that, once key firm characteristics (such as size, industry, cash flow) are controlled for, variation in ETR particularly between multinational and domestic firms, but also within a multinational firm over time reflects the degree of profit shifting and tax-minimization strategies—likely conducted by large, publicly-listed firms as those in our dataset.[20] On top of that, we also control for the $M\&A$ motive by including a dummy variable whether a firm acquired a new firm a year later in case globalization shocks might have increased a firm's appetite to acquire (particularly foreign) firms to enhance its global presence, which could in turn have incentivized firms to hold more cash to finance the acquisition. Similarly, since cash is also known to be frequently used for share buyback, we include a dummy variable indicating whether a firm conducted the share buyback program a year later.

The results of the main regressions that allow for alternative motives of cash holdings are summarized in Table 2.9. The signs of the coefficient estimates on the alternative channels are consistent with the above priors, and the estimated effects of the buyback and acquisition motives for cash holdings are particularly strong. However, none of the alternative channels turn out to affect the estimates of our main differential effect of export shocks, which retains statistical significance and similar magnitudes to the baseline results across all proxies of productivity differentials.

2.5 Conclusion

The last quarter century was an era of significant shifts in the global economy through trade, technology and political changes, including the transformation of global labor markets following the entry of China, India and countries of the former Eastern bloc into

[20]This is admittedly only a crude measure of the ex-post outcome of tax strategies: they include combined measure of domestic and foreign taxes, as well as current and deferred taxes that are reported in financial accounts. Changes in ETR can be also driven by changes in statutory tax rates over time and/or reflect the progressivity of the tax regime.

the world economy in the early 1990's. The period since the 2000's saw an acceleration of globalization following China's accession to the WTO and rapid increases in emerging markets' investment in infrastructure and education that led to a surge in their integration into world markets (Obstfeld, 2016). At the same time, large corporations across the world have become net lenders to the rest of the economy, accumulating unprecedented levels of cash on their balance sheets and investing increasingly in intangible capital.

In this paper, we show that these macro and micro-level trends are closely related. This occurs, as illustrated by our model, when globalization allows the most innovative and productive firms to capture a larger market, at the same time as higher innovation intensity exposes those firm to more liquidity risk in the interim, leading to more demand for cash arising from an optimal contract with outside investors. Using a comprehensive dataset covering the vast majority of publicly listed firms in five G7 economies, we provide evidence in support of the proposed mechanism, which could explain, on average, around 33 percent of the observed growth differential in cash holdings across firms in these countries. Given that globalization will advance in the long run, our paper's findings imply that firms' liquidity demand may increase as well, possibly increasing the demand for safe assets and entrenching the high corporate saving rates in many advanced economies. Conversely, the degree of financial frictions and quality of corporate governance structures which shape the ability of firms to obtain external and internal liquidity, can be of great importance for the process of exporter selection and the extent to which firms can reap the gains from global integration.

Bibliography

Aghion, P., Angeletos, G.-M., Banerjee, A., and Manova, K. (2010). Volatility and growth: Credit constraints and the composition of investment. *Journal of Monetary Economics*, 57(3):246–265.

Aghion, P., Bergeaud, A., Lequien, M., and Melitz, M. J. (2018). The Impact of Exports on Innovation: Theory and Evidence. NBER Working Papers 24600, National Bureau of Economic Research, Inc.

Aghion, P., Bloom, N., Blundell, R., Griffith, R., and Howitt, P. (2005). Competition and Innovation: an Inverted-U Relationship. *The Quarterly Journal of Economics*, 120(2):701–728.

Ahn, J. and Duval, R. (2017). Trading with China: Productivity gains, job losses. *Economics Letters*, 160(C):38–42.

Alexander, L. and Eberly, J. (2018). Investment Hollowing Out. *IMF Economic Review*, 66(1):5–30.

Armenter, R. (2012). The rise of corporate savings. *Business Review*, (Q3):1–8.

Armenter, R. and Hnatkovska, V. (2017). Taxes and capital structure: Understanding firms' savings. *Journal of Monetary Economics*, 87(C):13–33.

Atkeson, A. and Burstein, A. T. (2010). Innovation, Firm Dynamics, and International Trade. *Journal of Political Economy*, 118(3):433–484.

Autor, D., Dorn, D., Hanson, G. H., Pisano, G., and Shu, P. (2016). Foreign Competition and Domestic Innovation: Evidence from U.S. Patents. NBER Working Papers 22879, National Bureau of Economic Research, Inc.

Autor, D. H., Dorn, D., and Hanson, G. H. (2013). The China Syndrome: Local Labor Market Effects of Import Competition in the United States. *American Economic Review*, 103(6):2121–2168.

Azar, J. A., Kagy, J.-F., and Schmalz, M. C. (2016). Can Changes in the Cost of Carry Explain the Dynamics of Corporate "Cash" Holdings? *Review of Financial Studies*, 29(8):2194–2240.

Bates, T. W., Kahle, K. M., and Stulz, R. M. (2009). Why Do U.S. Firms Hold So Much More Cash than They Used To? *Journal of Finance*, 64(5):1985–2021.

Begenau, J. and Palazzo, B. (2017). Firm Selection and Corporate Cash Holdings. NBER Working Papers 23249, National Bureau of Economic Research, Inc.

Bernard, A. B., Jensen, J. B., Redding, S. J., and Schott, P. K. (2007). Firms in International Trade. *Journal of Economic Perspectives*, 21(3):105–130.

Bernard, A. B., Jensen, J. B., and Schott, P. K. (2009). Importers, Exporters and Multinationals: A Portrait of Firms in the U.S. that Trade Goods. In *Producer Dynamics: New Evidence from Micro Data*, NBER Chapters, pages 513–552. National Bureau of Economic Research, Inc.

Bloom, N., Draca, M., and Reenen, J. V. (2016). Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity. *Review of Economic Studies*, 83(1):87–117.

Bonfiglioli, A., Crino, R., and Gancia, G. (2018). Betting on Exports: Trade and Endogenous Heterogeneity. *Economic Journal*, 128(609):612–651.

Brown, J. R. and Petersen, B. C. (2011). Cash holdings and R&D smoothing. *Journal of Corporate Finance*, 17(3):694–709.

Bustos, P. (2011). Trade Liberalization, Exports, and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinian Firms. *American Economic Review*, 101(1):304–340.

Chaney, T. (2016). Liquidity constrained exporters. *Journal of Economic Dynamics and Control*, 72(C):141–154.

Chen, P., Karabarbounis, L., and Neiman, B. (2017). The global rise of corporate saving. *Journal of Monetary Economics*, 89(C):1–19.

Coelli, F., Moxnes, A., and Ulltveit-Moe, K.-H. (2016). Better, Faster, Stronger: Global Innovation and Trade Liberalization. CEPR Discussion Papers 11506, C.E.P.R. Discussion Papers.

Corrado, C. A. and Hulten, C. R. (2010). How Do You Measure a "Technological Revolution"? *American Economic Review*, 100(2):99–104.

Dao, M. and Maggi, C. (2018). The rise in corporate saving and cash holdings in advanced economies: aggregate and firm-level trends. *IMF Working Paper forthcoming*.

Dittmar, A., Mahrt-Smith, J., and Servaes, H. (2003). International Corporate Governance and Corporate Cash Holdings. *Journal of Financial and Quantitative Analysis*, 38(01):111–133.

Eisfeldt, A. L. and Papanikolaou, D. (2013). Organization Capital and the Cross-Section of Expected Returns. *Journal of Finance*, 68(4):1365–1406.

Fritz Foley, C., Hartzell, J. C., Titman, S., and Twite, G. (2007). Why do firms hold so much cash? A tax-based explanation. *Journal of Financial Economics*, 86(3):579–607.

Holmstrom, B. and Tirole, J. (1998). Private and Public Supply of Liquidity. *Journal of Political Economy*, 106(1):1–40.

(IMF), I. M. F. (2017). External sector report. July.

Lev, B. and Radhakrishnan, S. (2005). *Measuring capital in the new economy*, chapter The valuation of organization capital, pages pp. 73–110. University of Chicago Press.

Lileeva, A. and Trefler, D. (2010). Improved Access to Foreign Markets Raises Plant-level Productivity…For Some Plants. *The Quarterly Journal of Economics*, 125(3):1051–1099.

Lyandres, E. and Palazzo, B. (2016). Cash Holdings, Competition, and Innovation. *Journal of Financial and Quantitative Analysis*, 51(06):1823–1861.

Manova, K. (2013). Credit Constraints, Heterogeneous Firms, and International Trade. *Review of Economic Studies*, 80(2):711–744.

Markle, K. S. and Shackelford, D. A. (2012). Cross-Country Comparisons of Corporate Income Taxes. *National Tax Journal*, 65(3):493–527.

Mayer, T., Melitz, M. J., and Ottaviano, G. I. (2016). Product Mix and Firm Productivity Responses to Trade Competition. NBER Working Papers 22433, National Bureau of Economic Research, Inc.

Melitz, M. J. (2003). The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. *Econometrica*, 71(6):1695–1725.

Obstfeld, M. (2016). Get on track with trade. *Finance & Development*, 53 (4).

Pinkowitz, L., Stulz, R., and Williamson, R. (2016). Do us firms hold more cash than foreign firms do? *The Review of Financial Studies*, 29(2):pp.309–348.

Sim, J., Kadyrzhanova, D., and Falato, A. (2013). Rising Intangible Capital, Shrinking Debt Capacity, and the US Corporate Savings Glut. 2013 Meeting Papers 1151, Society for Economic Dynamics.

Srivastava, A. and Tse, S. Y. (2016). Why Are Successive Cohorts of Listed Firms Persistently Riskier? *European Financial Management*, 22(5):957–1000.

Subramanian, A. and Kessler, M. (2013). The Hyperglobalization of Trade and Its Future. Working Paper Series WP13-6, Peterson Institute for International Economics.

Tirole, J. (2006). *The theory of corporate finance*. Princeton University Press Princeton, N.J.

Vannoorenberghe, G. (2012). Firm-level volatility and exports. *Journal of International Economics*, 86(1):57–67.

Verhoogen, E. A. (2008). Trade, Quality Upgrading, and Wage Inequality in the Mexican Manufacturing Sector. *The Quarterly Journal of Economics*, 123(2):489–530.

2.6 Appendix

2.6.1 Tables

Table 2.1: Globalization and Cash Holding: China Shocks; OLS

	(1)	(2)	(3)	(4)
	No interaction	X=SIZE	X=SIZE	X=SIZE
expSHOCK	4.386***	4.228***	-2.851***	-2.386***
	(0.581)	(0.536)	(0.785)	(0.756)
expSHOCK_X2		-0.186	1.393***	0.918*
		(0.498)	(0.519)	(0.516)
expSHOCK_X3		0.419	4.389***	3.548***
		(0.719)	(0.857)	(0.814)
impSHOCK				-0.146**
				(0.0642)
impSHOCK_X2				0.210***
				(0.0789)
impSHOCK_X3				0.407***
				(0.0918)
Firm FE	Y	Y	Y	Y
Country-year FE	N	N	Y	Y
R2	0.720	0.720	0.732	0.732
N	57172	57172	57172	57172

Notes: This table presents results of panel OLS regressions examining the effect of export and import shocks *vis-à-vis* China on cash holding. Dependent variable is cash holding-to-assets ratio in log. All columns include firm fixed effects as well as other firm-level controls such as total sales, operating cash flow. Additional country-year fixed effects are inlcuded in columns 3-4. Tercile dummy variables based on total assets are also included but not reported in columns 2-4. Standard errors in parentheses are clustered at country-sector-year level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 2.2: Average of yearly medians for each country.

country	CashTA	Size	MB	Leverage	CF	RD2Sales	intangTA	Dividend	obs
FRANCE	.108	103	1.238	.178	.072	.033	.112	.538	13121
GERMANY	.094	125	1.263	.152	.076	.032	.06	.469	12602
JAPAN	.15	273	1.01	.205	.052	.012	.006	.81	65323
UK	.089	80	1.38	.131	.073	.03	.118	.559	24598
USA	.115	202	1.547	.151	.075	.078	.108	.228	83684

Source: Thomson Reuters Worldscope. $CashTA$ is the ratio of Cash and short-term investment over total book assets; MB is the market-to-book ratio; Size is expressed in Mn US Dollar; CF stands for cash flow in percent of asset, $RD2Sales$ is the median spending on R&D in percent of sales among firms with positive R&D spending (the unconditional median is zero), $intangTA$ is the share of declared intangibles to assets ratio; Dividend is the share of firms that pay dividend; *obs* is the total number of firm-year observations.

Table 2.3: Globalization and Cash Holding: China Shocks; 2SLS

	(1)	(2)	(3)	(4)
	No interaction	X=SIZE	X=SIZE	X=SIZE
expSHOCK	8.209***	7.229***	-5.435***	-5.187***
	(0.758)	(0.987)	(1.224)	(1.646)
expSHOCK_X2		-0.264	3.131**	2.769
		(1.280)	(1.342)	(1.967)
expSHOCK_X3		2.752*	8.177***	8.042***
		(1.483)	(1.456)	(2.098)
impSHOCK				-0.117
				(0.193)
impSHOCK_X2				0.101
				(0.244)
impSHOCK_X3				0.0212
				(0.268)
First stage	*Dep. var*: expSHOCK			
$expSHOCK(IV)$	1.248***[0.058]			
F-stat.	40.9			
Firm FE	Y	Y	Y	Y
Country-year FE	N	N	Y	Y
N	57172	57172	57172	57172

Notes: This table presents results of panel 2SLS regressions examining the effect of export and import shocks *vis-à-vis* China on cash holding. All columns include firm fixed effects as well as other firm-level controls such as total sales, operating cash flow. Additional country-year fixed effects are inlcuded in columns 3-4. Tercile dummy variables based on total assets are also included but not reported in columns 2-4. Standard errors in parentheses are clustered at country-sector-year level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 2.4: Globalization and Cash Holding: Firm-level China Shocks; 2SLS

	(1)	(2)	(3)	(4)
	No interaction	X=SIZE	X=SIZE	X=SIZE
expSHOCK	5.001***	4.467***	-0.729	-0.815
	(0.853)	(1.019)	(1.213)	(1.376)
expSHOCK_X2		-0.119	1.418	1.424
		(0.929)	(0.895)	(0.930)
expSHOCK_X3		1.259	4.221***	3.856***
		(1.035)	(1.052)	(1.054)
impSHOCK				-0.335
				(0.247)
impSHOCK_X2				-0.0444
				(0.193)
impSHOCK_X3				0.302
				(0.284)
First stage	*Dep. var*: expSHOCK			
$expSHOCK(IV)$	0.861***[0.131]			
F-stat.	43.4			
Firm FE	Y	Y	Y	Y
Country-year FE	N	N	Y	Y
Sector-year FE	N	N	Y	Y
N	63600	63600	63578	63567

Notes: This table presents results of panel 2SLS regressions examining the effect of firm-level export and import shocks *vis-à-vis* China on cash holding. Dependent variable is cash holding-to-assets ratio in log. All columns include firm fixed effects as well as other firm-level controls such as total sales, operating cash flow. Additional country-year and sector-year fixed effects are inlcuded in columns 3-4. Tercile dummy variables based on total assets are also included but not reported in columns 2-4. Standard errors in parentheses are clustered at two levels (country-year and sector-year). (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 2.5: Globalization and Cash Holding: Tariff; OLS

	(1)	(2)	(3)	(4)
	No interaction	X=SIZE	X=SIZE	X=SIZE
expMFN	-3.106***	-1.753***	1.330***	1.008**
	(0.602)	(0.541)	(0.467)	(0.476)
expMFN_X2		-1.393**	-1.320***	-0.837
		(0.531)	(0.476)	(0.622)
expMFN_X3		-2.058***	-2.063***	-1.655**
		(0.761)	(0.610)	(0.675)
impMFN				0.636
				(0.820)
impMFN_X2				-1.788*
				(0.965)
impMFN_X3				-1.735*
				(0.911)
Firm FE	Y	Y	Y	Y
Country-year FE	N	N	Y	Y
Sector-year FE	N	N	Y	Y
R2	0.713	0.713	0.731	0.730
N	45873	45873	45854	44162

Notes: This table presents results of panel OLS regressions examining the effect of export and import tariff changes on cash holding. Dependent variable is cash holding-to-assets ratio in log. All columns include firm fixed effects as well as other firm-level controls such as total sales, operating cash flow. Additional country-year and sector-year fixed effects are included in columns 3-4. Tercile dummy variables based on total assets are also included but not reported in columns 2-4. Standard errors in parentheses are clustered at two levels (country-year and sector-year). (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 2.6: The Underlying Channel of Globalization and Cash Holding: China Shocks; 2SLS

	(1)	(2)	(3)	(4)
	X=SIZE	X=SIZE	X=SIZE	X=SIZE
	innovative firms	non-innovative firms	DV:R&D spending	DV:SG&A spending
expSHOCK	-6.977***	3.537	-11.06***	-7.220***
	(1.760)	(5.963)	(2.960)	(1.489)
expSHOCK_X2	2.957	8.067	11.74***	8.940***
	(2.376)	(7.624)	(3.519)	(1.642)
expSHOCK_X3	8.747***	17.45	19.35***	11.56***
	(2.164)	(10.80)	(3.710)	(1.839)
impSHOCK	-0.0276	-0.0784	1.409**	0.494**
	(0.248)	(0.349)	(0.561)	(0.194)
impSHOCK_X2	-0.0926	0.0996	-0.843	-0.434*
	(0.400)	(0.428)	(0.715)	(0.223)
impSHOCK_X3	-0.230	0.0977	-2.056***	-0.630**
	(0.353)	(0.505)	(0.751)	(0.259)
Firm FE	Y	Y	Y	Y
Country-year FE	Y	Y	Y	Y
N	43782	13390	36782	51474

Notes: This table presents results of panel 2SLS regressions confirming the innovation channel through which export and import shocks *vis-à-vis* China affect cash holding. Dependent variable in columns 1 and 2 is cash holding-to-assets ratio in log, whille depedent variable in columns 3 and 4 is R&D spending-to-sales ratio and SG&A spending-to-sales ratio, respectively, both in log. Column 1 includes innovative firms only and column 2 includes non-innovative firms only. All columns include firm- and country-year fixed effects as well as other firm-level controls such as total sales, operating cash flow. Tercile dummy variables based on total assets are also included but not reported. Standard errors in parentheses are clustered at country-sector-year level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 2.7: Globalization and Cash Holding: China Shocks; 2SLS; Alternative firm proxies

	(1)	(2)	(3)	(4)	(5)	(6)
	X=LP	X=LP	X=EXP	X=EXP	X=NIPE	X=NIPE
expSHOCK	-3.513***	-4.436***	-10.89***	-13.34***	-7.726***	-5.763**
	(1.030)	(1.716)	(2.357)	(3.420)	(1.959)	(2.907)
expSHOCK_X2	2.410*	2.919	8.122***	9.867**	5.244	-2.783
	(1.421)	(2.251)	(2.894)	(4.044)	(3.982)	(6.850)
expSHOCK_X3	12.70***	15.39***	9.039***	12.40***	19.04***	20.54***
	(2.177)	(3.209)	(2.197)	(3.509)	(2.854)	(3.875)
impSHOCK		0.291		0.341		-0.383
		(0.380)		(0.331)		(0.517)
impSHOCK_X2		-0.237		-0.287		1.740
		(0.420)		(0.340)		(1.078)
impSHOCK_X3		-0.819*		-0.678		-0.289
		(0.496)		(0.418)		(0.560)
Firm FE	Y	Y	Y	Y	Y	Y
Country-year FE	Y	Y	Y	Y	Y	Y
N	54929	54929	40059	40059	54911	54911

Notes: This table presents results of panel 2SLS regressions examining the effect of export and import shocks *vis-à-vis* China on cash holding for innovative firms. Dependent variable is cash holding-to-assets ratio in log. All columns include firm- and country-year fixed effects as well as other firm-level controls such as total sales, operating cash flow. Tercile dummy variables included but not reported in this table is based on labor productivity (columns 1-2), the share of foreign sales in total sales (columns 3-4), and net income per employee (columns 5-6). Standard errors in parentheses are clustered at country-sector-year level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 2.8: Cash flow volatility and globalization shocks

	(1)	(2)	(3)	(4)
	All firms	SG&A$<$ *median*	SG&A$>$ *median*	SG&A$>$ $75thpctile$
exp_SHOCK	-3.696**	-0.401**	-7.409*	-31.26*
	(1.862)	(0.172)	(4.132)	(17.53)
exp_SHOCK_X2	3.506**	0.192	7.143*	29.29*
	(1.785)	(0.210)	(3.942)	(16.99)
exp_SHOCK_X3	3.440*	0.152	7.043*	30.72*
	(1.883)	(0.193)	(4.218)	(17.62)
imp_SHOCK_X1	0.477*	0.0361*	1.045	4.879*
	(0.282)	(0.0197)	(0.671)	(2.941)
imp_SHOCK_X2	-0.498*	0.00941	-1.091	-4.616
	(0.290)	(0.0327)	(0.694)	(2.894)
imp_SHOCK_X3	-0.498*	-0.0232	-1.065	-5.069*
	(0.297)	(0.0429)	(0.688)	(3.047)
Firm FE	Y	Y	Y	Y
Country-year FE	Y	Y	Y	Y
N	36430	16997	18901	10845

Notes: This table presents results of panel 2SLS regressions examining the effect of export and import shocks *vis-à-vis* China on cash flow volatility, defined as the standard deviation of cash flow/asset rate over the subsequent 5-year window. Dependent variable is standard deviation of cash flow/asset ratio over the subsequent 5 years. All columns include firm- and country-year fixed effects as well as other firm-level controls such as total sales, operating cash flow. Tercile dummy variables included but not reported in this table is based on firm's total assets (size). Standard errors in parentheses are clustered at country-sector-year level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

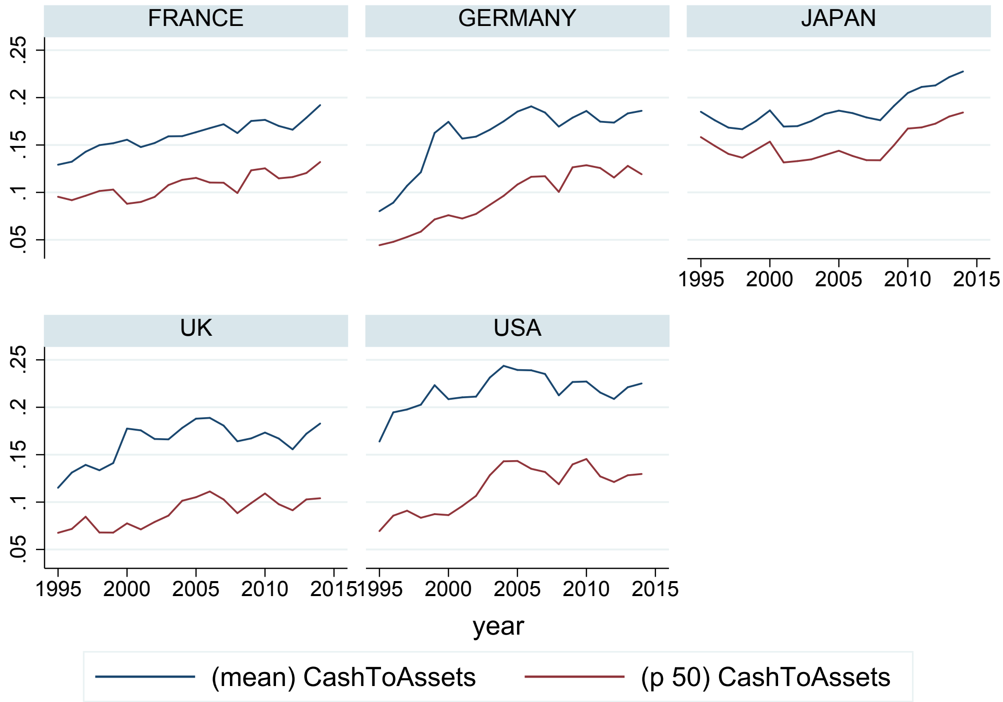
Table 2.9: Globalization and Cash Holding: China Shocks; 2SLS; Controlling for Other Motives

	(1)	(2)	(3)	(4)
	X=SIZE	X=LP	X=EXP	X=NIPE
expSHOCK	-3.112	-1.812	-12.61***	1.867
	(2.183)	(1.690)	(3.913)	(3.576)
expSHOCK_X2	1.341	2.161	13.20***	-11.81
	(2.362)	(2.187)	(4.481)	(7.389)
expSHOCK_X3	5.163**	6.138**	11.19***	8.744***
	(2.360)	(2.750)	(3.879)	(2.949)
impSHOCK	-0.377	0.0844	0.180	-0.438
	(0.239)	(0.386)	(0.346)	(1.138)
impSHOCK_X2	0.497*	-0.205	-0.300	1.375
	(0.286)	(0.426)	(0.349)	(1.562)
impSHOCK_X3	0.286	-0.134	-0.241	-0.0344
	(0.283)	(0.433)	(0.394)	(1.197)
EffectiveTaxRate	-0.0882	-0.0971	0.196	-0.0796
	(0.431)	(0.436)	(0.272)	(0.460)
Acquisition	9.399***	9.187***	10.65***	9.118***
	(1.445)	(1.459)	(1.570)	(1.608)
BuyBack	1.064***	1.175***	1.350***	1.107***
	(0.163)	(0.170)	(0.201)	(0.177)
Firm FE	Y	Y	Y	Y
Country-year FE	Y	Y	Y	Y
N	37209	36117	25928	36116

Notes: This table presents results of panel 2SLS regressions examining the effect of export and import shocks *vis-à-vis* China on cash holding, controlling for alternative motives for cash holding. Dependent variable is cash holding-to-assets ratio in log. All columns include firm- and country-year fixed effects as well as other firm-level controls such as total sales, operating cash flow, effective tax rate, M&A, share buyback. Tercile dummy variables included but not reported in this table is based on total assets (column 1), labor productivity (column 2), the share of foreign sales in total sales (column 3), and net income per employee (column 4). Standard errors in parentheses are clustered at country-sector-year level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

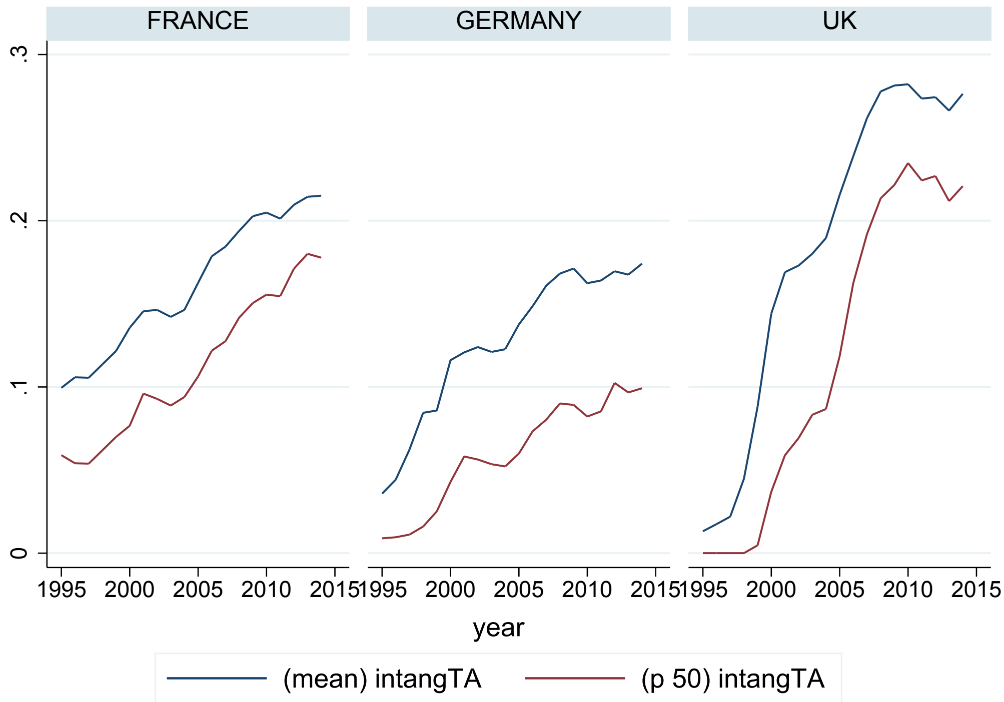
2.6.2 Figures

Figure 2.1: Cash and short-term investment in percent of total assets: mean and median.



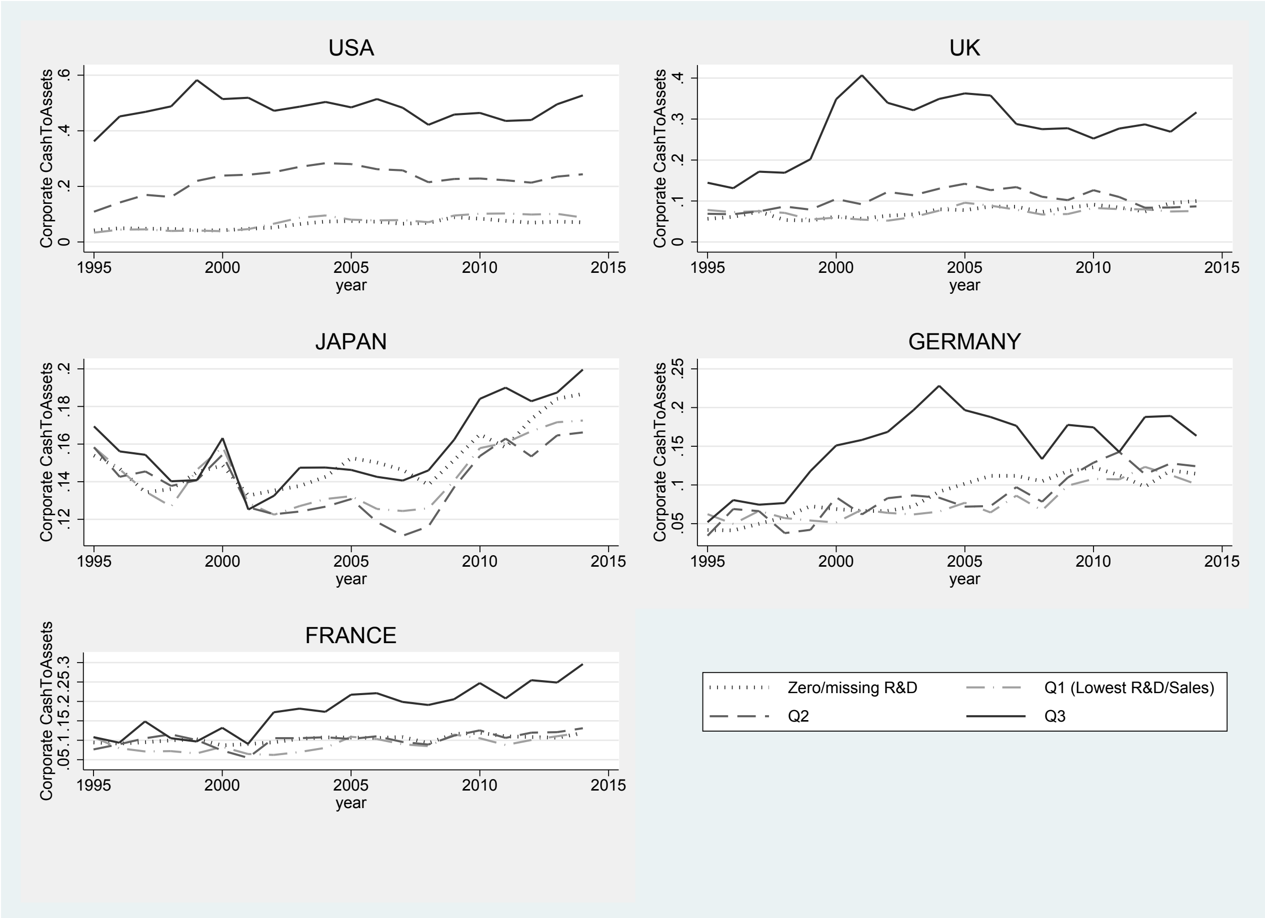
Source: Thomson Reuters Worldscope and authors' calculations. Cash to asset ratios are measured by the ratio of cash and short-term instruments to overall book assets. Mean and median cash ratios are calculated for each country year for firms with valid non-missing data.

Figure 2.2: Intangible capital as a share of total assets: mean and median.



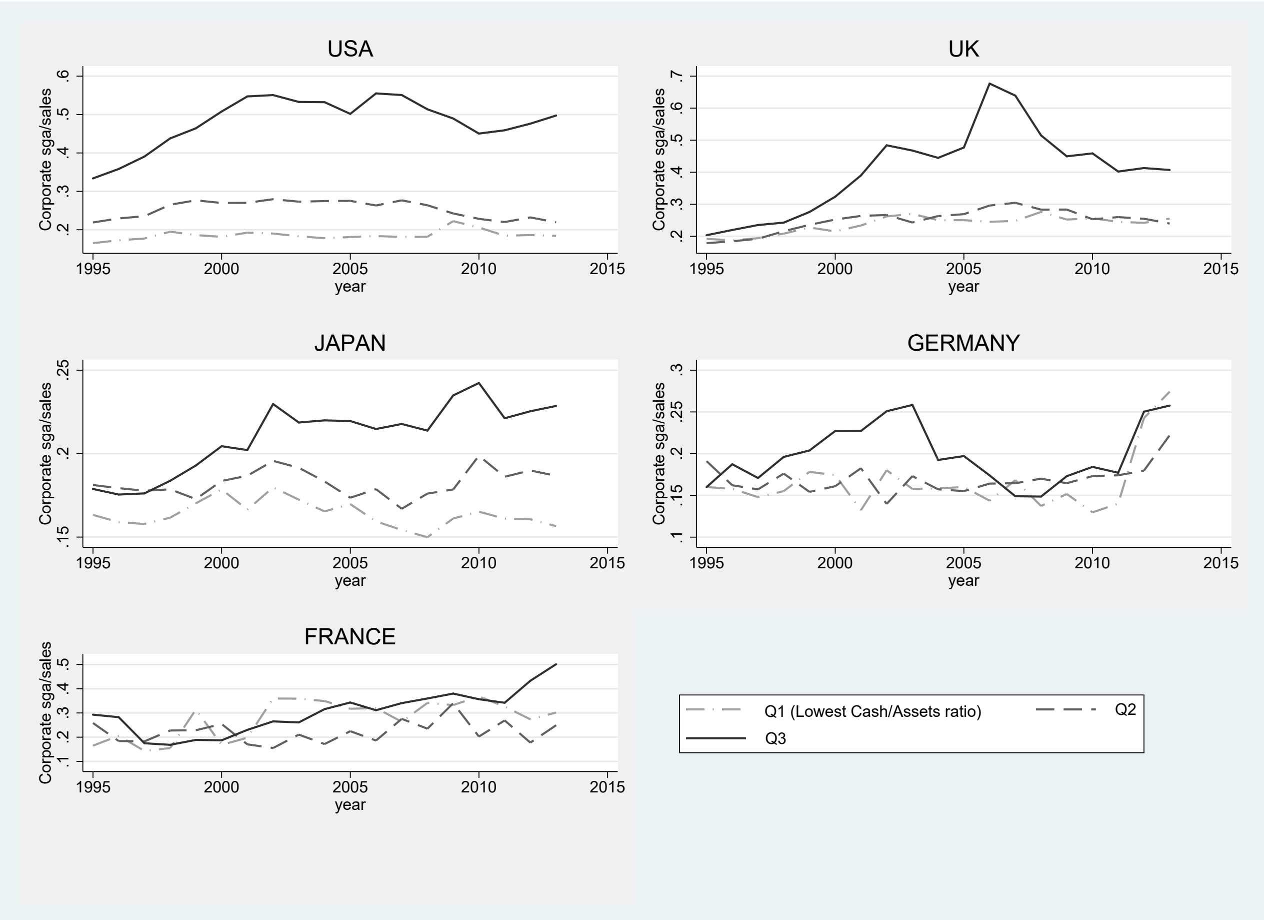
Source: Thomson Reuters Worldscope and authors' calculations. Mean and medians in each country year are calculated for firms with non-missing valid entries for intangible assets.

Figure 2.3: cash holdings evolution by innovation intensity.



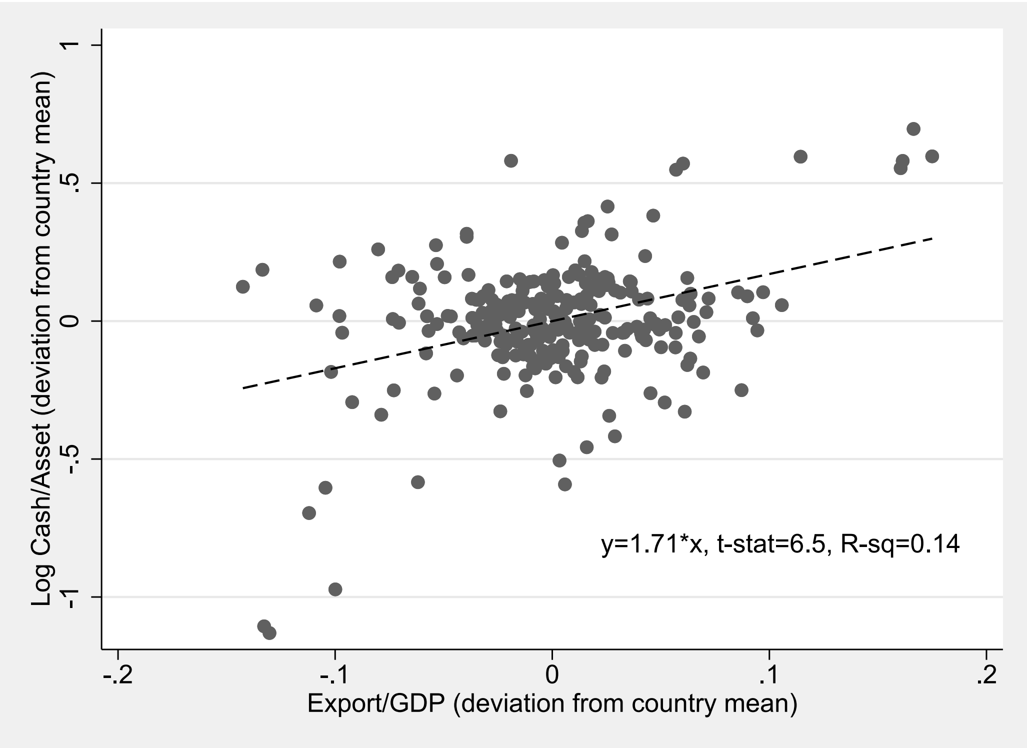
Source: Thomson Reuters Worldscope and authors' calculations. Cash to asset ratios are measured by the ratio of cash and short-term instruments to overall book assets, winsorized at the top and bottom 1 percent. Firms with positive *R&D* are sorted into terciles of innovation intensity (measured by R & D/sales ratio) in each country year. The lines indicate the median cash to asset ratio within each tercile of innovation intensity for each country year, and the median cash to asset ratio for firms with zero or missing R&D data.

Figure 2.4: SG& A evolution by cash-ratio.



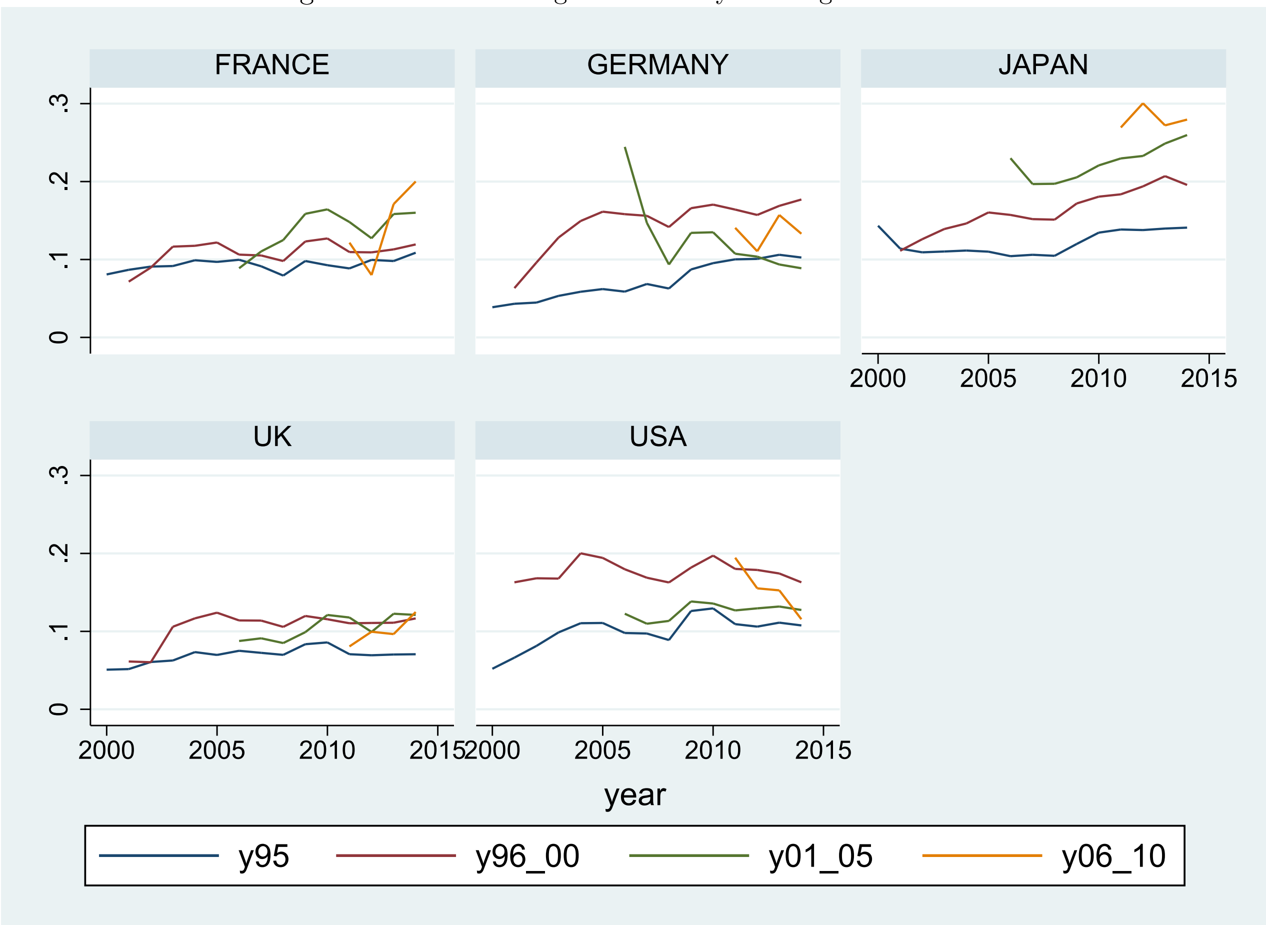
Source: Thomson Reuters Worldscope and authors' calculations. Cash to asset ratios are measured by the ratio of cash and short-term instruments to overall book assets, winsorized at the top and bottom 1 percent. The lines indicate the median SG& A spending (in percent of sales) within each tercile of cash ratio for each country year.

Figure 2.5: Aggregate export shares and cash ratios



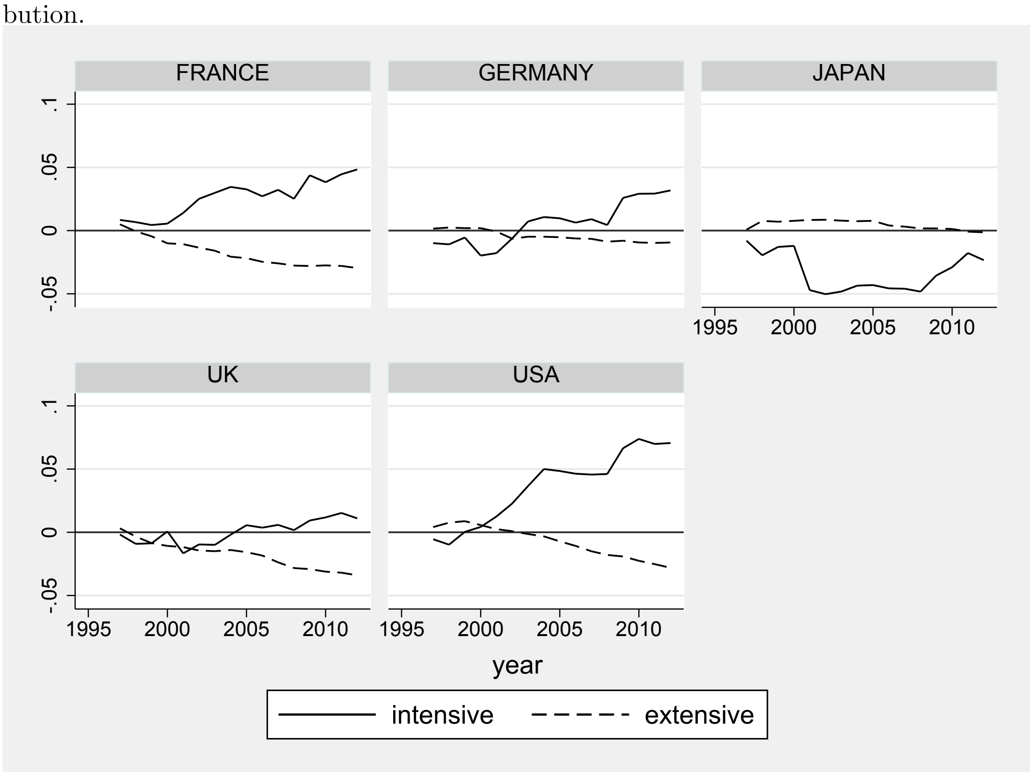
Source: OECD Sectoral Financial Accounts, IFS and authors' calculations. Cash to asset ratios are measured by the ratio of cash and short-term instruments to total financial assets. All values are in deviation from country mean during the period 1995-2015.

Figure 2.6: cash holdings evolution by entering cohorts.



Source: Thomson Reuters Worldscope and authors' calculations. Cohorts are defined as set of firms that appear for the first time in the sample during each consecutive 5-year window. Lines show the median cash to asset ration within each cohort over time.

Figure 2.7: Decomposition of aggregate cash ratio to cumulative intensive and extensive margin contribution.



Source: Thomson Reuters Worldscope and authors' calculations. The decomposition of total change into intensive and extensive margin contributions follows equation (2.1) in the text. Cash to assets ratios are winsorized at the top and bottom 1 percent. Only firms with at least 2 consecutive observations of non-missing cash ratios are included.

Figure 2.8: Timing of events in the baseline 3-period model.

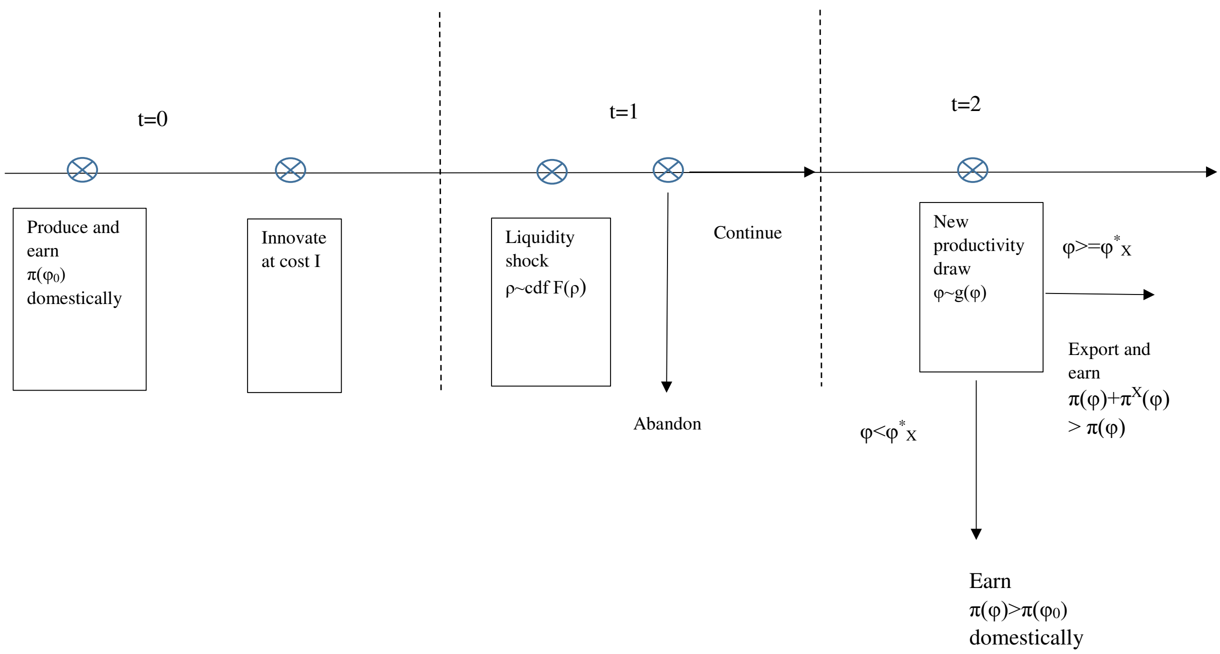
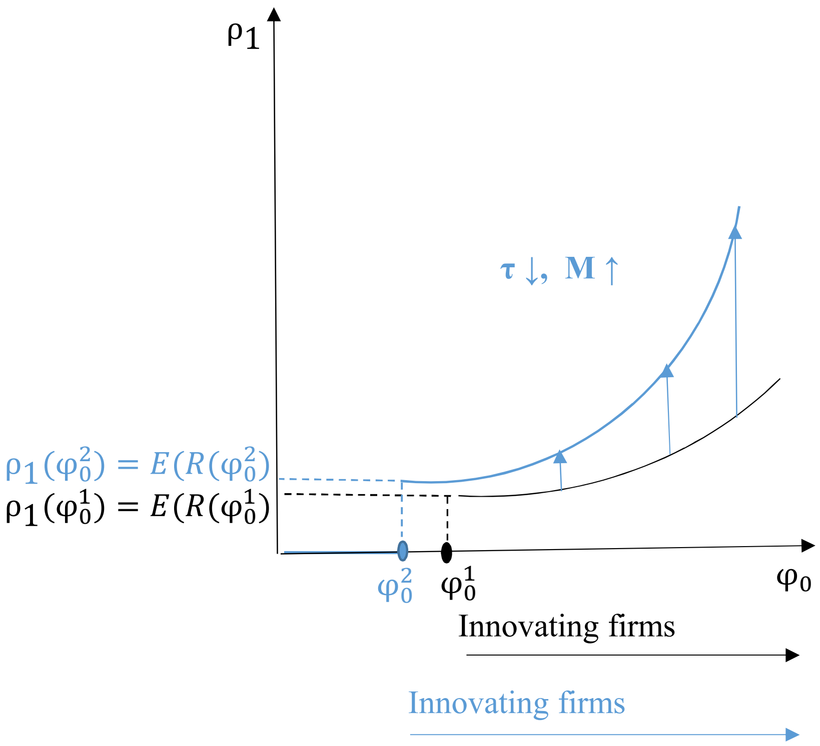
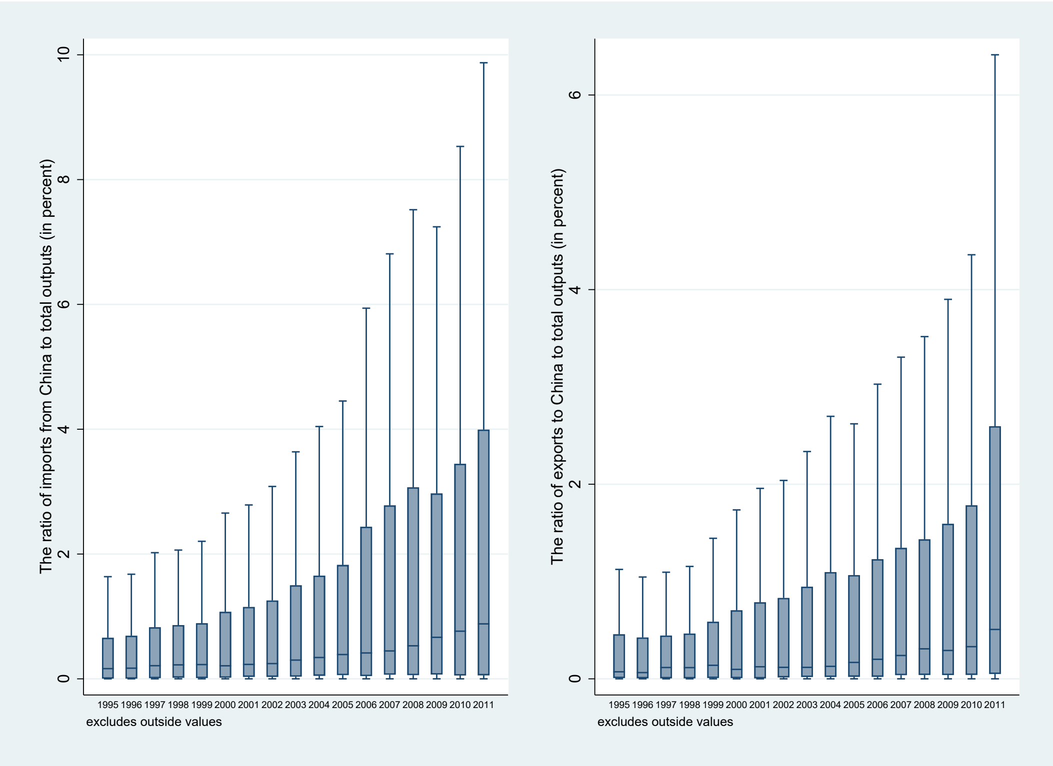


Figure 2.9: Set of innovating firms and schedule of cash holdings as a function of initial productivity ϕ_0.



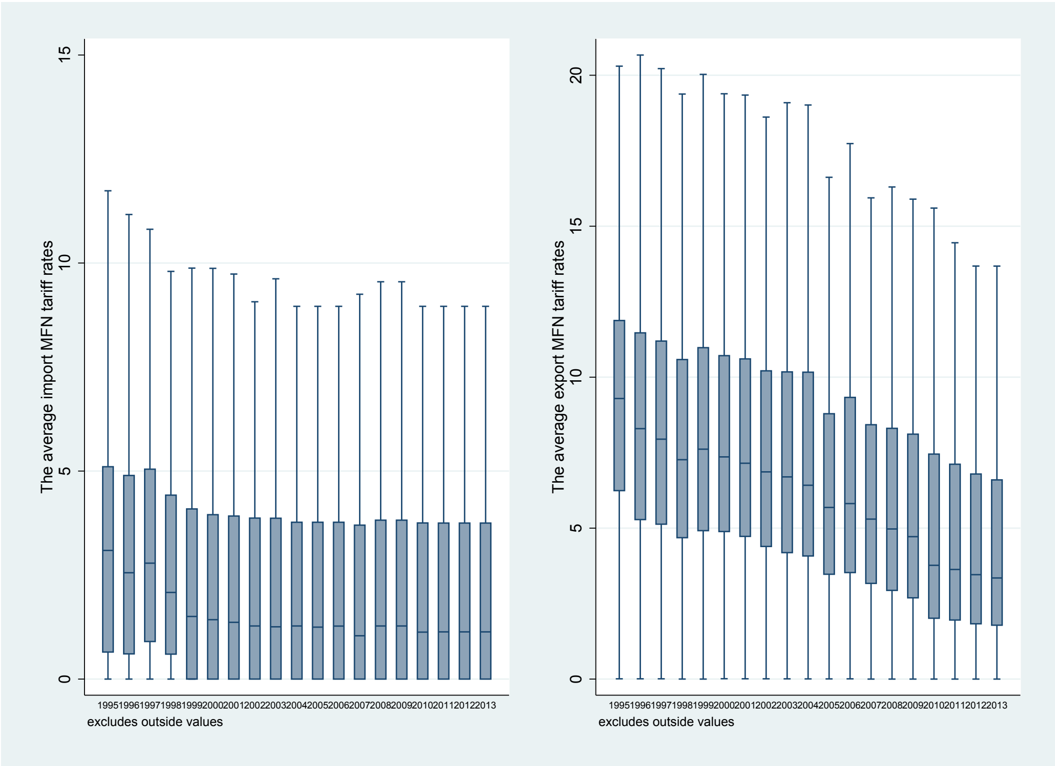
Note: Shift after trade liberalization is sketched in blue. Productivity cutoff for innovators are indexed by 1 and 2 before and after shift.

Figure 2.10: The evolving role of China in global trade.



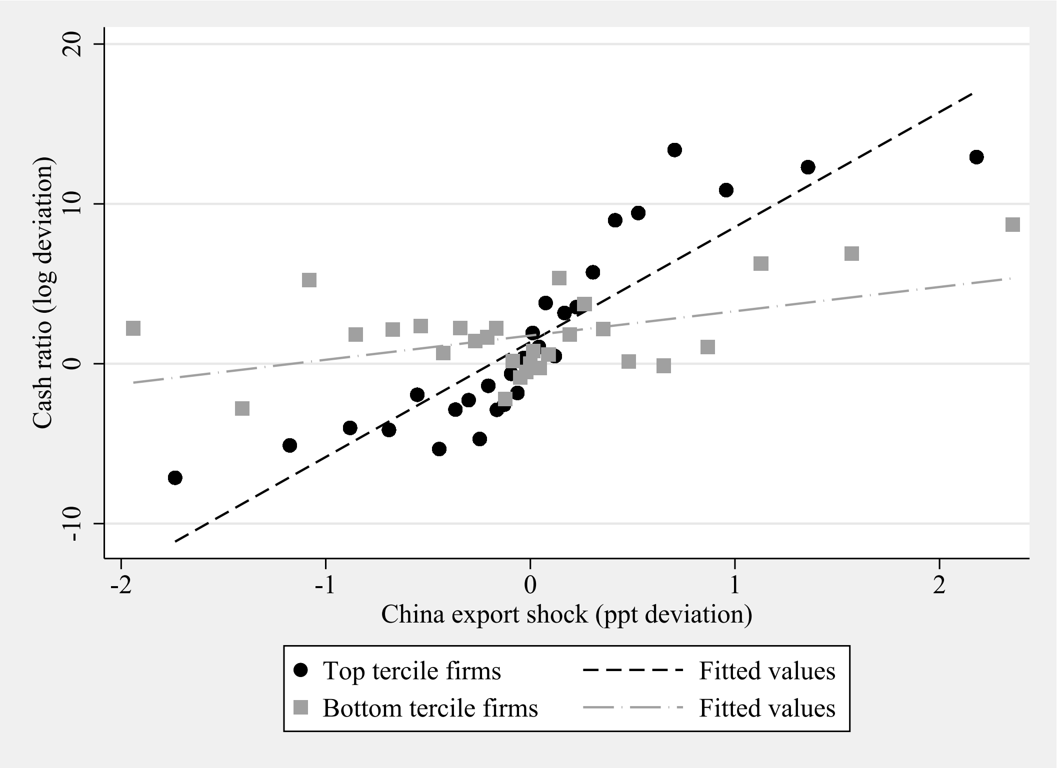
Source: World Input Output Database (WIOD) and authors' calculations; Country-2digit sector level distribution.

Figure 2.11: Global tariff liberalization.



Source: UN Comtrade, TRAINS, and authors' calculations; Country-2digit sector level distribution.

Figure 2.12: cash holdings increases with higher export demand, more so for larger firms.



Notes: higher export demand is associated with higher cash holdings, but only significantly so for large firms, i.e. those within the top tercile of asset size distribution of a given country-year. The dots represent the average within each of the 25 quantiles of the China shock (measured as change in export share to China from third countries by industry, weighted by the firm's sales share in its 2 main industries), absorbing the firm fixed effects, plotted against the corresponding quantile-average of log cash holdings, conditional on the firm fixed effect. The conditional correlation is plotted separately for firms in the top and bottom tercile of the country-specific asset size distribution.

2.6.3 Deriving the expected profit from innovating

Preferences

As in a one-sector Melitz (2003) model, the preference of a representative consumer (in domestic and export markets) is given by the CES utility function over a continuum of varieties indexed by ω:

$$U = \left[\int_{\omega \epsilon \Omega} q(\omega)^{\frac{\sigma-1}{\sigma}} d\omega\right]^{\frac{\sigma-1}{\sigma}}, \sigma > 1$$

where σ is the elasticity of substitution between varieties. Denoting the price of each variety as $p(\omega)$, the aggregate price index associated with the aggregate consumption basket of all varieties is then given by the Dixit-Stiglitz aggregator:

$$P = \left[\int_{\omega \epsilon \Omega} p(\omega)^{(1-\sigma)} d\omega\right]^{\frac{1}{1-\sigma}}$$

and the demand for each individual variety given by:

$$q(\omega) = Q\left[\frac{p(\omega)}{P}\right]^{\sigma},$$

where Q denotes the exogenous real income (in terms of the aggregate consumption basket) of the consumer.

Problem of the firm

All firms are monopolistically competitive and and hire labor (which is inelastically supplied) to produce a distinct variety ω. Firms differ in their inherent (labor) productivity ϕ (or marginal cost $1/\phi$), representing the quantity of outputs (of their variety) produced with each unit of labor. Profit maximization for given wage cost (normalized to one) leads a firm with productivity ϕ to set its price according to the mark-up rule:

$$p(\phi) = \frac{\sigma}{1-\sigma}\frac{1}{\phi},$$

and realize profits in the domestic markets of:

$$\pi(\phi) = M\phi^{\sigma-1},$$

where M is an aggregate demand shifter given by $M = \left(\frac{\sigma}{\sigma-1}\right)^{\sigma-1}\frac{QP^{\sigma}}{\sigma}$, and taken as given by the firm.

Prior to innovating, all firms are equal and realize the profit level $\pi(\phi_0) = M\phi_0^{\sigma-1}$. Upon drawing a new productivity level $\phi \geq \phi_0$ after innovating, each firm obtains profits in domestic markets given by $\pi^D = M\phi^{\sigma-1} > M\phi_0^{\sigma-1}$. Moreover, it can export to foreign markets and obtain additional profits π^X after paying fixed costs f_X and incurring iceberg cost τ per unit of output sold abroad. Therefore, the firm will only export if and only if:

$$\pi^X(\phi) = M^X \left(\frac{\phi}{\tau}\right)^{\sigma-1} - f_x \geq 0 \iff \phi \geq \phi^* = \tau \left(\frac{f_x}{M_X}\right)^{\frac{1}{\sigma-1}}$$

Ex-ante expected profits of the firm, are then given by:

$$E(\pi) = \int_{\phi_0}^{\infty} M\phi^{\sigma-1} g(\phi) d\phi + \int_{\phi_X^*}^{\infty} \left[M^X \left(\frac{\phi}{\tau}\right)^{\sigma-1} - f_X\right] g(\phi) d\phi \tag{2.10}$$

which is the equation in the text. We can obtain closed form solution for expected profits by assuming that new productivity draws are distributed according to the Pareto distribution with the cdf:

$$G(\phi) = 1 - \left(\frac{\phi_0}{\phi}\right)^{\kappa}, \phi \geq \phi_0, \ \kappa > \sigma - 1.$$

Substituting the density function $g(\phi) = G'(\phi)$ into equation (2.10), we obtain:

$$E(\pi) = \frac{M\kappa}{\kappa - \xi}\phi_0^{\xi} + \frac{\kappa f_x}{\kappa - \xi}\phi_X^*(f_x, \tau, M^x)^{-\kappa}\phi_0^{\kappa}, \tag{2.11}$$

which is equation (2.4) in the text.

2.6.4 Model extension: external financing and moral hazard

In this extension of the baseline model, we allow the firm to borrow from outside investors anytime. We now move one step back to the stage after which the firm has survived the liquidity shock but before it draws the new productivity. Prior to drawing the new productivity, the firm can decide to "shirk" and not put its best effort into the project. By doing so, the firm effectively draws its productivity from an alternative Pareto distribution $h(\phi)$ with shape parameter $\lambda > \kappa$, where h has thinner right tail so that the average productivity is lower than under g, as more probability mass is concentrated around the lower bound ϕ_0 (see Figure 2.13). In addition, since shirking is not verifiable ex-post, the firm gets to keep private benefits B regardless of the actual productivity realization, subjecting the innovation project to moral hazard.[21]. Suppose that the contract with the lender specifies that the firm retains a fraction of its profits in the domestic market, that is, conditional on the productivity draw ϕ, the firm is paid $R_f(\phi) = \eta\pi^D(\phi), \eta < 1$, while the rest, $\pi(\phi) - R_f(\phi) = (1-\eta)\pi^D(\phi) + \pi^X(\phi)$, goes to the lender. Then the firm will

[21]Moral hazard is essential to understand credit rationing and liquidity demand. In the absence of moral hazard, if the NPV of the project exceeds the liquidity shock and firms can issue claims up to the full value of the NPV, there will be no need for liquidity hoarding as the firm can borrow instantaneously when the shock arrives or issue shares to obtain the funding.

put its best effort and not shirk if and only if $E_G(R_f(\phi)) \geq E_H(R_f(\phi)) + B$ (where the subscripts G, H refer to the cdf over which the expectation is taken). This is the case if and only if:

$$\eta \geq \eta_{min} = \frac{B/M}{\phi_0^{\xi}\xi\left(\frac{\kappa}{\kappa-\xi} - \frac{\lambda}{\lambda-\xi}\right)} \tag{2.12}$$

The contractual payment to the firm to ensure its best effort is larger, the larger the private benefit (that it can hide from the lender) and the smaller the difference between the two distributions G and H (captured by the difference between λ and κ), that is, the more difficult it is for the lender to distinguish between shirkers and non-shirkers.[22] On the other hand, the required payment to the firm is lower, the higher its initial productivity, as the expected return from exerting best effort is higher.

Now moving to $t = 1$, conditional on being hit by a liquidity shock ρ, it immediately follows that the firm should continue whenever $\rho \leq \rho^1 = E_G(\pi(\phi))$, that is when the cost overrun does not exceed the expected profit from continuing the innovation. This is the first-best cutoff that may or may not be chosen by the financial contract in $t = 0$.

In $t = 0$, assuming the net present value of the innovation project is positive (which effectively introduces a minimum productivity threshold for innovating firms), the firm will want to innovate and require external funding I plus enough liquidity to insure against the liquidity shock in $t = 1$. What is the optimal financial contract between the firm and a lender that can be implemented to provide firms with the necessary funding, maximizes the payoff to each party, and is incentive compatible so the firm does not shirk? The timing of the events in this extended version of the model is summarized in Figure 2.14.

The optimal contract

As in Holmström and Tirole (1998), competition among lenders drives their ex-ante expected profit to zero. The optimal financial contract therefore maximizes the payoff to the firm, subject to the break even condition for the lender and the incentive compatibility constraint. The contract is implemented by the liquidity cutoff level ρ^*, which also corresponds to the firm's level of cash holdings, and the fraction of profit left for the firm η:

The optimal contract between the firm and its lender solves the following problem:

$$max_{\rho^*,\eta} \int_0^{\rho^*} E_G(R_f) f(\rho) d\rho \tag{2.13}$$

[22] Letting payoff to the firm only depend on profit from domestic sales comes with algebraic tractability without loss of generality. Intuitively, if the return to the firm was a fraction of total profits (domestic and foreign), then more export opportunities will lower the η_{min} necessary to ensure the firm's incentive compatibility and therefore raise pledgable income, which will in turn raise the optimal level of cash holdings ρ^* even more.

subject to:

$$\int_0^{\rho^*} [E_G(R) - E_G(R_f) - \rho] f(\rho)d\rho = I \quad (2.14)$$

$$E_G(R_f) = \eta E_G(R^D) \quad (2.15)$$

$$\eta \geq \eta_{min} \quad (2.16)$$

The solution of this maximization problem follows closely Tirole (2006). Substituting the lender's break-even constraint (2.14) and the payout rule (2.15) into the objective function of the firm, we can reformulate the problem to:

$$max_{\rho^*,\eta} \int_0^{\rho^*} [E_G(R) - \rho] f(\rho)d\rho - I = max_{\rho^*,\eta} \left\{ E_G(R)F(\rho^*) - \int_0^{\rho^*} f(\rho)d\rho - I \right\} \quad (2.17)$$

subject to the break-even condition (2.14) and the incentive compatibility (IC) condition (2.16).

As the objective function is the overall return from the innovation project, it is maximized when

$$E_G(\pi)f(\rho^*) - \rho^* f(\rho^*) = 0, \quad (2.18)$$

that is when the cut-off is at the first-best level $\rho^* = \rho^1(\phi_0) = E_G(R(\phi_0))$, same as in the baseline model in the main text. However, this cut-off is only feasible if it satisfies the lender break-even constraint (2.14), in other words, if the pledgable income at first-best cash level P_1, which is increasing in productivity, is at least as large as the initial outlays I for the lender. This is the case if:

$$P_1(\phi_0) = P(\rho^1(\phi_0)) = F(\rho^1)\left[E_G(\pi) - \eta_{min}E_G(\pi^D)\right] - \int_0^{\rho^1} \rho f(\rho)d\rho \geq I \quad (2.19)$$

In this high-productivity scenario, substituting ρ^1 into the break-even condition (2.14) delivers the equilibrium η, which can be shown to fulfill the IC constraint (2.16).[23]

If condition (2.19) is not satisfied, then the first-best cut-off cannot be implemented and the optimal liquidity level ρ^* is strictly lower than the first best level ρ^1. This follows immediately from the fact that pledgeable income $P(\rho^*)$ is decreasing in ρ^* and that ρ^1 already maximizes (2.17). Moreover, as the pledgeable income is decreasing in η, it follows immediately that the optimal η, the share of profits left to the firm, is always given by $\eta = \eta_{min}$, the minimum level to satisfy the IC constraint. The optimal cut-off $\tilde{\rho}$

[23]Indeed, because the maximum pledgeable income $P(\rho^1) \geq I$ is evaluated at $\eta = \eta_{min}$, and the pledgeable income function $P(\rho^1, \eta)$ is decreasing in η, reducing the pledgeable income from above to equal $I - A$ implies raising η above η_{min}, introducing slack into IC constraint (2.16).

is then pinned down by the break-even condition, that is, it is implicitly given by:

$$\int_0^{\tilde{\rho}} \left[E_G(\pi) - \eta_{min} E_G(\pi^D) - \rho\right] f(\rho) d\rho = I \tag{2.20}$$

or:

$$F(\tilde{\rho}) \left[E_G(\pi) - \eta_{min} E_G(\pi^D)\right] - \int_0^{\tilde{\rho}} \rho f(\rho) d\rho = I$$

Finally, if initial productivity is too low, such that the maximum pledgeable income is less than the initial outlays of the lender, no contract can be written and the firm undertakes no innovation. This is the case if:

$$P(\rho_0(\phi_0), \eta_{min}) < I, \tag{2.21}$$

where $\rho_0(\phi_0)$ is the cut-off level that maximizes the pledgeable income to the lender for any given initial productivity of the firm, derived by setting the first derivative of (2.19) to zero: $\rho^0 = E_G(\pi) - \eta_{min} E_G(\pi^D) < \tilde{\rho} < \rho^1$.

Overall, the higher is I, the more likely it becomes that the pledgeable income from innovation, for a given level of productivity, is not sufficient to cover the initial outlays.[24] For a *given* level of I, the level of cash holdings is dependent on the level of productivity of the firm, and we obtain the following results corresponding to the main results in the text. To summarize, the solution to the contract above gives the following decision rule for innovation and optimal level of cash holdings, depending on the initial productivity of the firm:

- If $P_0(\phi_0) = P(\rho_0(\phi_0), \eta_{min}) < I \rightarrow \phi_0 < \tilde{\phi}_0 = P_0^{-1}(I)$: low productivity - do not innovate[25]
- If $P_0(\phi_0) = P(\rho_0, \eta_{min}) \geq I \rightarrow \phi_0 \geq \tilde{\phi}_0 = P_0^{-1}(I)$: sufficient productivity - innovate. Moreover:
  - If $P_0^{-1}(I) \leq \phi_0 < P_1^{-1}(I)$: intermediate productivity - innovate and hold cash amount $\tilde{\rho}$;
  - If $\phi_0 \geq P^{-1}(I)$: high productivity - innovate and hold cash amount ρ^1.

The schedule for optimal cash holdings as a function of initial productivity is depicted in Figure 2.15 and we obtain qualitatively similar results as in the baseline model as follows.

[24] In particular, all firms will be able to hold the first-best cash level ρ_1 if $I \leq P_1(\phi_{min})$ and no firm will be able to innovate if $I > P_0(\phi_{max})$ if ϕ_{min}, ϕ_{max} are the min-max boundaries of the initial productivity distribution.

[25] Note that this minimum threshold $\tilde{\phi}_0$ is above the minimum productivity $\phi_0 = P_1^{-1}(I)$ that guarantees a positive NPV of the innovation project in the first-best and the baseline model, in other words $P_0^{-1}(I) > P_1^{-1}(I)$, following from the fact that $P_1(.)$ is strictly larger than $P_0(.)$ for any given level of productivity (in turn as maximum pledgeable income is only a fraction of total NPV).

Result 1 extended *Only firms above a minimum productivity cutoff will innovate. Innovating firms hold more cash than non-innovating firms. Innovating firms with higher initial productivity hold more cash.*

The firm will not be able to obtain funding and innovate if its initial productivity ϕ_0 is below the minimum level at which the maximum pledgeable income is lower than the initial outlays. That is, no innovation and cash holdings for firms with productivity lower than $\tilde{\phi}_0 = P_0^{-1}(I)$, where P_0^{-1} is the inverse function of the maximum pledgeable income P_0, equal to pledgeable income $P(.)$ evaluated at $\rho^0 = E_G(\pi) - \eta_{min} E_G(\pi^D) < \rho^1$.

On the other hand, if productivity is above the upper cutoff ϕ_{max} where $P_1(\phi_{max}) \geq I$, then the firm is unconstrained in the sense that its pledgeable income at the first-best cash level is enough to cover the initial outlays, and will thus always be able to hold the first-best cash level ρ_1 (as in the baseline model).

When initial productivity is in the range $P_0^{-1}(I) < \phi_0 < P_1^{-1}(I)$, the optimal cutoff ρ^*, i.e. the cash holdings of the firm resulting from the optimal contract with the investor will be determined by the break-even condition of the lender:

$$P(\rho^*((\phi_0)) = F(\rho^*) \left[E_G(R(\phi_0) - \eta_{min}(\phi_0) E_G(R^D(\phi_0)) \right] - \int_0^{\rho^*} \rho f(\rho) d\rho = I. \qquad (2.22)$$

Call the level of the cutoff solving this condition to be $\rho^* = \tilde{\rho}$. As in the baseline model, firms with higher productivity hold more cash to withstand a larger liquidity shock, either because they are unconstrained and expect a higher NPV from innovation (if $\phi_0 \geq \phi_{max}$), or because they are constrained but are able to commit to more pledgeable income (if $\tilde{\phi}_0 < \phi_0 < \phi_{max}$). This relationship is depicted by the solid black curve in Figure 2.15.

Result 2 extended *Conditional on being an innovating firm, globalization in terms of lower trade costs τ and/or expanded foreign market size M^X increases the level of the firm's cash holdings, that is $\frac{\partial \rho^1}{\partial \tau} < 0$, $\frac{\partial \rho^*}{\partial M^X} > 0$. Moreover, more productive firms increase their cash holdings more in response to the same shock than less productive ones.*

Recall that cash holdings of the innovating firm equals $\rho^* = \rho^1 = E_G(R(\phi_0))$ if it has high initial productivity $\phi_0 \geq \phi_{max} = P_1^{-1}(I)$. In this case, it immediately follows that $\frac{\partial \rho^1}{\partial M^X} > 0$ as larger export markets increase expected profits from innovating by increasing the probability of becoming an exporter (lowering the exporter cutoff ϕ_X^*) and by increasing profit from exporting conditional on drawing a high enough productivity. If the firm's initial productivity lies in the intermediate range $P_0^{-1}(I) \leq \phi_0 < P_1^{-1}(I)$, then by implicit function theorem applied to the optimality condition (2.22), we have:

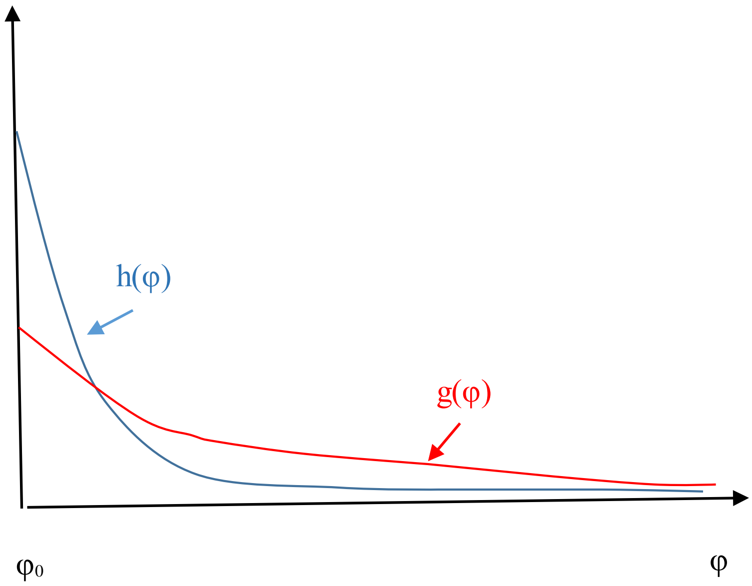
$$\frac{\tilde{\rho}}{\partial M^X} = \frac{F(\tilde{\rho})}{f(\tilde{\rho})(\tilde{\rho} - \rho_0)} \frac{\partial E(R)}{\partial M^X} > 0 \qquad (2.23)$$

and thus, conditional on being an innovator, i.e. on having sufficiently high productivity, the level of cash holdings always increases with higher export markets (or lower trade costs τ). Finally, the first term of $\frac{\partial \tilde{\rho}}{\partial M^X}$ is increasing in $\tilde{\rho}$, which in turn is increasing ϕ_0 (per Result 1 above), while the second term corresponds to $\frac{\partial \rho^1}{\partial M^X}$ and therefore also increasing in ϕ_0. Thus, subject to the same positive export shock, a higher underlying productivity will lead to a stronger boost to cash holdings. This shift is depicted by the blue arrows and associated solid blue curve in Figure 2.15.

Result 3 extended *Globalization in terms of lower trade costs τ and/or expanded foreign market size M^X reduces the productivity threshold for innovation and thus, for a given distribution of initial productivity across firms, increases innovation activity and the average cash holdings among incumbent firms in the industry.*

As discussed in Result 1, the minimum productivity threshold for innovation depends negatively on the level of pledgable income, which in turn depends positively on the ex-ante expected profit from innovating. By raising the returns from exporting for high productivity firms, a decrease in τ increases ex-ante expected profit from innovating as shown in equations (2.2) and (2.4). This increases the cutoff level $\rho^0 = E_G(R) - \eta_{min} E_G(R^D)$ which maximizes the pledgeable income and thus the maximum pledgeable income $P_0(\phi_0)$ for any productivity ϕ_0. As more income can be pledged and the pledgeable income schedule shifts up, the minimum productivity level $P_0^{-1}(I)$ for firms to obtain funding to innovate is lowered. If the distribution of initial productivity ϕ_0 is taken as exogenous in each industry, lower trade costs/larger export markets increase the share of firms that innovate and, as these firms have higher cash holdings than non-innovating firms by the amount $\rho*$, also increases the average cash holdings in the industry.

Figure 2.13: Distribution of new productivity draw if firm behaves (g) and when it shirks (h).



Note: Productivity distribution after innovation and after surviving the liquidity shock.

Figure 2.14: Timing of events in the extended 3-period model.

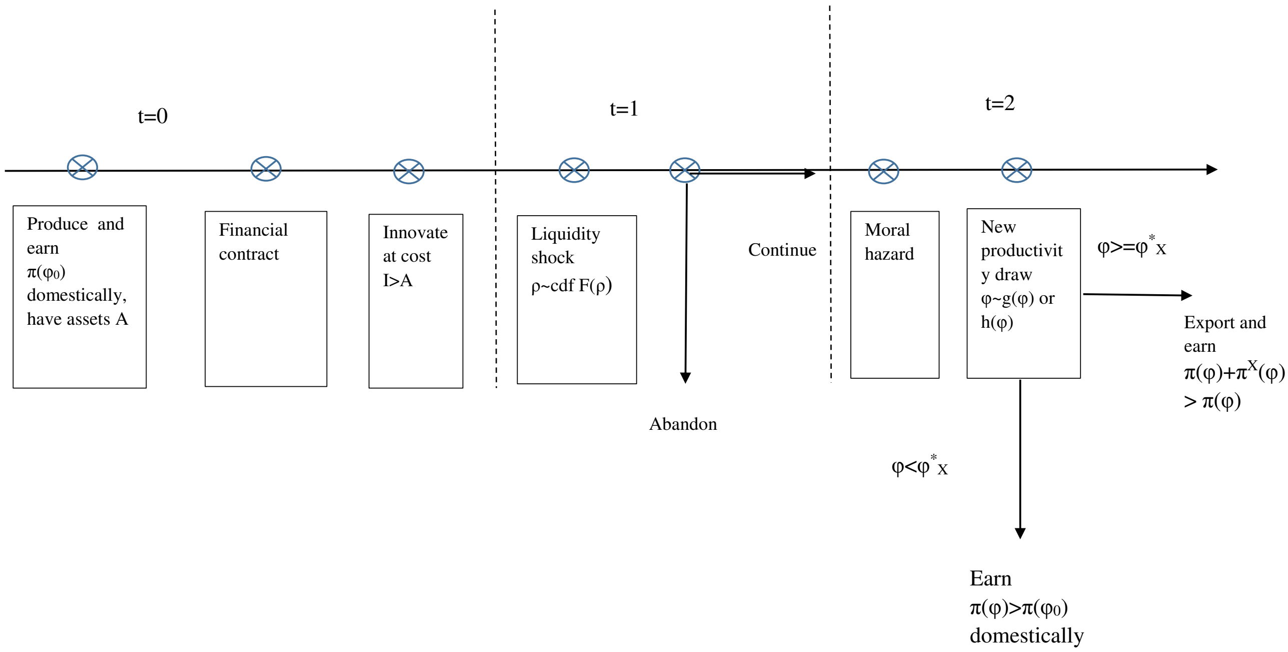
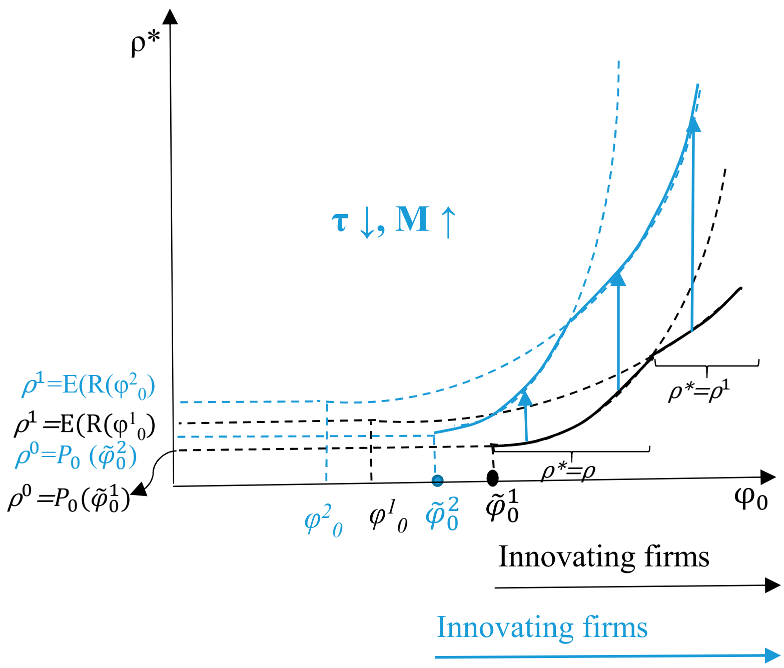


Figure 2.15: Set of innovating firms and schedule of cash holdings as a function of initial productivity ϕ_0.



Note: Shift after trade liberalization is sketched in blue. Productivity cutoff for innovators are indexed by 1 and 2 before and after shift.

Chapter 3

Globalization and Taste Heterogeneity: Evidence from Hollywood

Konrad Adler and Simon Fuchs

Abstract
To what extent is the set of products available to a country driven by the composition of international markets? We develop a quantitative framework to determine taste heterogeneity and to analyze changes in the international market structure. We apply our framework to the global movies market where we can abstract from price competition and observe identical products and their market shares across countries. We evaluate the hypothesis that the observed large increase in the revenue share of sequels has been due to shifts in the composition of global demand away from traditional Western markets towards emerging countries. This shift might have increased the penalty of "missing the mark" in the taste space and therefore caused an increase in sequel production. While we do find substantial shifts in the profit space and lower risk associated with sequels, our current simulations suggest that the risk due to taste heterogeneity in the movies market is quantitatively insufficient to explain the increase in the revenue of sequels, suggesting that other forces such as scale economies might be at play.

3.1 Introduction

2015 was a successful year for Hollywood, with the global box office increasing to 38.3 billion dollars (MPAA 2015) and with the top performing American productions capturing the largest part of the revenue. Creativity, however, seems to have reached a low-point: Amongst the top 10 highest performing movies[1] only one movie can be categorized as original work with no preceding media products. Among the rest we find six franchises (James Bond, Hunger Games, Star Wars, Jurassic Park, Avengers/Marvel, Fast and Furious), a book adaptation (The Martian), and a remake (Cinderella). In 2015 sequels or franchises made up almost 60 percent of the yearly revenue up from around 30 percent at the beginning of the 2000s. Simultaneously, the composition of the global movie market has shifted dramatically with the US and Western European markets becoming less important compared to Asia, Eastern Europe and other markets. To what extent and how did these demand shifts influence creativity and the product mix in Hollywood? More generally, how does the composition of global markets with countries affect the product mix?

Traditional trade theory has often abstracted from this question because a measure of taste heterogeneity across countries is needed to provide an answer and has been difficult to estimate.[2] Yet global market integration and the increasing importance of Emerging countries, in particular the rise of China, most likely influence the product mix and thus affect consumer welfare gains from globalization.

We suggest that the global box office offers a convenient setting to examine the mechanisms that link taste heterogeneity across countries to the product mix. Several reasons make the international movies market particularly attractive for this exercise. Firstly, studios produce and then distribute a single product with fixed observable characteristics that is being released across multiple markets without (major) adjustment. Market specific revenues and thus market shares are readily available and we collected a unique and large dataset combining several online sources. To the extent that the dataset is complete, the available product bundle (that is alternative movies released at the same time) can be readily constructed while the market structure is such that price competition between movies at the boxoffice is of little importance. This implies that - conditional on controlling for selective release of movies across markets - the covariation of market shares across countries is informative about taste similarity between countries.

[1]The top 10 at the global box office in 2015 was as follows: 1. Star Wars: The Force Awakens (937 MM), 2. Jurassic World (652 MM), 3. Avengers: Age of Ultron (459 MM), 4. Inside Out (356 MM), 5. Furious 7 (353 MM), 6. Minions (336 MM), 7. The Hunger Games: Mockingjay - Part 2 (281 MM), 8. The Martian (228 MM), 9. Cinderella (201 MM), 10. Spectre (200 MM)

[2]While market shares of identical products across countries could be informative about the taste for specific characteristics of given products, differences in market structure and available product bundles have made it difficult to directly estimate these differences. Furthermore, while trade data might be available at a relatively high level of disaggregation even at the 8-digit level HS code there can still be substantial heterogeneity in terms of product characteristics and quality.

Our analysis proceeds in four steps: In a first step we present two stylized facts about the global box office: (1) The share of sequels and adapted content has increased dramatically over recent decades, (2) the global movies market has experienced major shifts away from the traditional 'Western' target audience.

In a second step we use a random utility framework where we decompose the global appeal of a product, i.e. movie, across all markets and the relative appeal between markets by introducing an artificial taste space with fixed positions of countries where market shares are decreasing in the distance between a movie from the location of individual countries. This relative distance of countries is pinned down by the covariation of market shares across movie observations and we estimate a two dimensional space with all country locations from the box office revenues of more than 1000 movie released since 2001. The framework is reminiscent of the address type models explored amongst others by Anderson et al. (1989), but rather than mapping heterogeneity in demand into observed characteristics we focus on unobservable heterogeneity.

In a third step we argue that studios make their production decision by picking locations in this abstract taste space, but face uncertainty in the form of a displacement shock along the two dimensions of the taste space. The variance of the shock can be estimated using a moment inequality approach focusing on movies that are - given their production budget - ex post not profitable and determining the closest position for which the movie would have had positive expected profits - the distance to the observed position can be used to determine a lower bound for the variance of the displacement shock. This procedure can also be implemented across movie types. We find substantial uncertainty across all movie types, but less uncertainty for sequels which tend to be more closely placed in the vicinity of their predecessors. This suggests that in a more multi polar market sequels might be advantageous by reducing the 'spatial' risk in the abstract taste space.

Finally, we conduct counterfactuals by simulating the global revenue share of sequels in the absence of changing market conditions.

This paper contributes to two literatures: The first being the traditional literature on the movies market and cultural economics more broadly speaking as surveyed recently by McKenzie (2012). We abstract from much of the usual features that are the center of attention of other studies and instead focus on the interaction between the global market place for movies, implied demand uncertainty and choice of type of movies in an abstract yet tractable setting.

The second literature is a nascent literature on taste heterogeneity and supply in global markets, where the closest study is a recent examination of the global cars market by Coşar et al. (2018). They examine taste heterogeneity estimated in a BLP framework with a particular focus on the question to what extent preferences for the home brand can account for the home market effect commonly observed in the data. While they focus on the home market effect, our focus is on understanding how shifts in global markets affect products supplied to all markets.

The paper proceeds as follows: The next section introduces the data and stylized facts, section three introduces the quantitative model, the fourth section introduces the estimation and finally section five presents the details of the simulation of movie markets and describes the results for a counterfactual simulation of the movies market in the absence of the rise of China. The final section concludes.

3.2 Data and Stylized Facts

Data We use data from BoxOfficeMojo which has information about the production cost and the boxoffice revenues for a set of countries for each movie. A second data source is TheNumbers which has detailed information about the source of the screenplay of a movie, i.e. original screenplay, book adaptation. We use the "connections" section from The Internet Movie Database to find the title and release year of sequels.

The sample period is 2001-2017. We exlude movies with missing information about the production budget and no information about boxoffice revenue outside the US. Finally we restrict our sample to movies that generated at least $80 million in boxoffice revenue. The final dataset has 1009 movies including boxoffice revenue data from up to 59 countries. Table 3.1 shows summary statistics of our main variables. Out of the 254 sequels in our sample we are able to match 142 to their prequel[3]. For the estimation we split each year into five seasons commonly used in the movie industry: Winter, Spring, Summer, Fall and Holiday season. Movies compete against each other within each season but not necessarily during an entire year.

The left hand side graph in figure 3.1 shows that a higher production budget results in a larger boxoffice revenue on average but the remaining uncertainty in movie production is considerable. Film studios are using different ways to reduce this uncertainty. One important way is to produce a movie based on a theme or story that has been successful previously. Examples of this "recycling" of content are remakes, sequels and adaptations of books and TV series. In this paper we focus on sequels as a way to reduce uncertainty. The right hand side graph in figure 3.1 compares the distribution of profits for sequels and non-sequels. Sequels indeed reduce the risk for a loss and earn on average a higher profit compared to non-sequels.

Stylized facts Our first stylized fact is shown on the left hand side graph in figure 3.2: between 2001 and 2017 the share of sequels in total boxoffice revenue has increased from around 30 to almost 50%. When adding remakes and other non-original content the increase is even more pronounced. At the same time the share of non-US boxoffice

[3]Most unmatched sequels have a prequel released before our sample period starts

revenue in total revenue increased from 40 to 65%. This is our second stylized fact. The increase in the share of non-US boxoffice revenue comes from emerging countries. All regions except Western Europe and other developped countries (Japan, South Korea, Australia, New Zealand) become more important between 2001 and 2013 as shown in figure 3.3. After 2013 the increase in the non-US revenue share is mainly due to the increasing importance of Asia.

3.3 Model

We present a random utility framework where we decompose the global appeal of a product, i.e. movie, across all markets and the relative appeal between markets by introducing an artificial taste space with fixed positions of countries where market shares are decreasing in the distance between a movie from the location of individual countries. This approach is closely related to the address based approach where both consumers and products are represented by a location in a characteristic space and where the consumers location pins down his optimal product as explored by - among others - Anderson et al. (1989). On the supply side, firms choose their location in that characteristics space. Rather than defining the dimensions of this space in terms of actually observed characteristics, we map the observed demand patterns into an unobserved heterogeneity space, which we call taste space. This allows us to reduce the dimensionality of movie characteristics without imposing a lot of structure.

3.3.1 Demand side

We posit a random utility model (RUM), where the utility of consumer i who chooses product j (in our case a specific movie), is given by,

$$U_{ij} = \alpha_i(w_i - p_j) + \xi_j + \epsilon_{ij}$$

$$\epsilon_{ij} = \sum_l \gamma_l |c_j^l - c_i^l| + u_{ij}$$

where w_i is the income of the consumer, p_j the price of product, ξ_j an unobservable that is constant across all consumers. The error term is structurally decomposed into a mean zero, double exponentially distributed error term , u_{ij} and a term that measures the distance in a n-dimensional taste space whose dimensions are denoted by l, where the vector c_j denotes the position of the product and the vector c_i the position of the consumer. Consumers will be distributed around a midpoint for each given country as described below. The utility is a decreasing function in the distance - that is the $L1$ norm - between consumer and product location, where the sensitivity to the distance along each dimension is measured by γ. The probability for consumer i to choose product j is given by the following,

$$Pr(i,j) = Pr(u_{ij} > u_{ik}, \forall k \neq i)$$

which under symmetric prices (p_i=p_k) translates into,

$$= Pr(\xi_j + \sum_l \gamma_l |c_j^l - c_i^l| + u_{ij} > \xi_k + \sum_l \gamma_l |c_k^l - c_i^l| + u_{ik}$$

$$= Pr\left(\xi_j + \sum_l \gamma_l |c_j^l - c_i^l| - (\xi_k + \sum_l \gamma_l |c_k^l - c_i^l|) > u_{ik} - u_{ij}\right)$$

which assuming logit errors gives us the familiar reduced form for the probability of consumer i choosing product j,

$$Pr(i,j) = \frac{\exp(\xi_j + \sum_l \gamma_l |c_j^l - c_i^l|)}{\sum_k \exp(\xi_k + \sum_l \gamma_l |c_k^l - c_i^l|)}$$

The market share of product j across all the consumers in a given country c, that is the set of consumers I_c, is given by the integral across all consumers in that country,

$$s_j^c = \frac{p_j q_j}{\sum_k p_k q_k} = \int_{i \in I_c} \frac{\exp(\xi_j + \sum_l \gamma_l |c_j^l - c_i^l|)}{\sum_k \exp(\xi_k + \sum_l \gamma_l |c_k^l - c_i^l|)} di$$

While for each individual consumer the independence of irrelevant alternatives property holds, for the aggregate market share that is not the case. Specifically, the relative market share of two products, depends on how they affect different consumers in the consumer space individually, and how that aggregates. If a certain group of consumers is already well provided for, with many products in their close vicinity, locating an additional product there might bring lower revenues, than serving a less competitive section in the consumer space.

3.3.2 Supply side

There is a large number of entrepreneurs each endowed with a movie script. A movie script, j, is defined by a triplet consisting of an expected location in the taste space, $\tilde{c}_j$, the production cost, b_j, and the content type, that is a variable s_j which assumes the value 1 if the script is a sequel. Uncertainty comes from a taste shock for each dimension where the vector of disturbances is denoted by ε_j which is the difference between the expected taste location of the script $\tilde{c}_j$ and the actualized - ex-post - taste location c_j of the movie, i.e.

$$c_j = \tilde{c}_j + \varepsilon_j \quad \text{where} \quad \begin{cases} \varepsilon \sim G(0, \Sigma_{\text{sequel}}) & \text{iff} \quad s_j = 1 \\ \varepsilon \sim G(0, \Sigma_{\text{no sequel}}) & \text{iff} \quad s_j = 0 \end{cases}$$

where the disturbance vector ε is drawn from a zero mean distribution that features a lower variance if the script is a sequel rathern than a original script. In addition a sequel's taste location is linked to its prequel. We assume entrepreneurs to make no mistake about the taste location of their script on average for both sequels and non-sequels, which implies a zero mean disturbance. Entrepreneurs are risk-neutral and maximize profits by making a discrete choice to produce a script if and only if expected profits are positive, i.e.

$$\mathbb{E}\pi(\tilde{c}_j, b_j, s_j) \geq 0$$

where $\mathbb{E}\pi((\tilde{c}_j, b_j, s_j)$ refers to the expected profits of a script with expected location $\tilde{c}_j$, budget b_j and of type s_j. Each entrepreneur takes the location and production choice of other entrepreneurs as given.

3.4 Estimation

The estimation of the quantitative model proceeds in two steps. In a first step we will exploit co-variance of revenue shares of movies across countries together with the framework introduced above to estimate the relative location of countries towards each other. In a second step we will then use a moment inequality approach to exploit the assumption that only movies that are in expected terms profitable would have been produced to back out the uncertainty in the taste space associated with the production of different types of movies (notably, sequels vs non sequels).

3.4.1 Demand side

Estimation procedure We assume that consumers within a given country c, are distributed according to a normal distribution, with a fixed mean and variance, independently across all dimensions, that is,

$$c_i^l \sim N(\mu_c^l, \sigma_c^l) \quad for \quad i \in I_c$$

The model can then be estimated by simulated methods of moments. That is we simulate markets by drawing consumer locations given the mean and variance, and then choose ξ_j to minimise the distance between observed and market shares for the products within countries and across countries, that is we target s_j^c for all j and for all c that we observe. The objective to be minimized is as follows,

$$\eta_{j,c,t}\left(\mu_c, \sigma_c, \xi_j, \gamma, c_j\right) = \frac{q_j}{\sum_k q_k} - \int_{i \in I_c} \frac{\exp(\xi_j + \sum_l \gamma_l |c_j^l - c_i^l|)}{\sum_k \exp(\xi_k + \sum_l \gamma_l |c_k^l - c_i^l|)} di$$

Since we can only determine the relative distance between countries and thereby the relative location of countries and movies in the taste space, some normalization is necessary to obtain a well defined taste space and all positions. We normalize the space by calibrating the γ parameters and choosing a location for the most important market - that is the US.[4]

Results The estimated taste space is depicted in figures 3.5 and 3.6. The figures present the location of individual countries as well as simulated revenue contours for 2001 and 2017. Revenue contours are obtained by introducing a grid of location at which we place homogenous movies with identical ξ_j and production budget. The contours can then be obtained by calculating the profit given the observed market size for each country (i.e. the total observed box office revenues in a given year and country) for each location along the grid and smoothing across them. The traditional and more established markets are tightly clustered together in close proximity to the US market at the mid point of the space. Asian markets cluster in the North-West quadrant of the space. Asian markets and particularly China exert a pull on the profit space that becomes visible at the end of the sample in 2017.

In figures 3.7 and 3.8 we furthermore map the revenue difference between a movie at precisely the indicated location and the expected profit of a movie that is facing the probability of a small disturbance into all directions. In the baseline year it is particularly important to have precision in the center of the taste space to match exactly the most important markets and not to lose market shares to competing movies - this creates an advantage for sequels with potentially lower production uncertainty. Towards the end of the sample in 2017 we observe that there are additional zones where lower variance movies are advantageous, creating more demand for sequels. While this illustrates the possibility for taste heterogeneity to create demand for lower variance products, the quantitative impact depends on the precise size of different parameters, such as the distance penalty parameter as well as the relative and absolute size of the shocks across product groups.

We also obtain the taste locations of movies. We regress taste space coordinates of movies on their observable characteristics. Table 3.3 shows that movies with high values in the second taste dimension for example, tend to be IMAX format, Horror and Science-fiction movies.

[4] For computational convenience we also impose lower and upper bounds and choose a value for γ such that all countries are contained within that space. Effectively we estimate a two dimensional space between 0 and 1 for both dimensions and assign the US the midpoint position at $(.5, .5)$.

3.4.2 Supply side

We estimate Σ, the variance-covariance matrix of the taste shock, separately for sequels and non-sequels. For sequels we compute the variance of the distance in the taste space between each sequel and its prequel:

$$\Sigma_{\text{sequel}} = E[(c_{\text{sequel}} - c_{\text{prequel}})^2]$$

For non-sequels we search for a sequence of taste shocks such that: first, the likelihood of observing the actual taste location is maximized and second, expected profits at the script location, i.e. actual location plus taste shock, are positive. We assume taste shocks to be jointly normally distributed and to have zero covariance between taste dimensions. Because only the absolute value of the distance between expected and actual taste location matters for Σ we maximize the likelihood with respect to the distance d and compute expected profits for all combinations of signs of d.

$$\max_{\{d^2\}} \sum_i logL(|d|, \Sigma_{\text{no sequel}})$$
$$s.t. \pi(\tilde{c}_i) \geq 0$$

where $\pi(\tilde{c}_i)$ refers to the expected profit at the initially chosen location, the constraint requires the initial location to have expected positive profits[5], and where $\Sigma = E[d^2]$ is the implied variance-covariance matrix to be estimated.

Results The estimated variance along each dimension for both sequels and non sequels is reported in table 3.2. Sequels have substantially lower estimated production uncertainty along both dimensions.

3.5 Simulation & Counterfactual

Sequels offer a trade off: They promise lower production uncertainty but at the price of locating a movie close to the predecessor at what is potentially a less than optimal location in the profit space. We argue that when market shares shift and the profit space

[5] More precisely, because the pdf is symmetric the sign of the difference between the realized taste and the script location does not matter for the log likelihood, that is the actual constraint is as follows,

$$\begin{aligned} max(\pi(\tilde{c}_i^+, \Sigma_{\text{no sequel}})], \pi(\tilde{c}_i^-, \Sigma_{\text{no sequel}})]) \geq 0 \\ \tilde{c}_i^+ = c_i + d \\ \tilde{c}_i^- = c_i - d \\ 0 \leq d^2 \end{aligned}$$

becomes riskier, then sequels might become more attractive than original productions, shifting the global product mix and the observed revenue share for that type of product.

In this section we employ the quantitative model and estimated taste space to examine that quesiton. We first describe how to simulate the model for a specific period, using the estimated location of consumers of individual countries as well as the uncertainty of sequels and non sequels as inputs and determining a set of movies that populates the taste space and clears the market conditional on the market size and the arrival frequency of sequels as script ideas. Secondly, we show how to use this approach to obtain a simulated time series for the sequel revenue share that tracks the revenue share in the data from the early 2000s to 2017. Finally, we demonstrate the counterfactual revenue share if the distribution of income across countries would have remained constant at 2001 levels.

3.5.1 Static Simulation and Time Series

To simulate the movie market for a given period we take the country locations and budgets as given. We start by drawing a large number[6] of movie scripts which are identical in their global appeal, and budget, i.e.

$$\xi_j = \bar{\xi} \qquad \forall j$$

$$b_j = \bar{b} \qquad \forall j$$

Scripts do however differ in their location across the taste space. The location of different scripts is drawn uniformly along both dimensions of the space. We then iterate over two steps: We first calculate the profits under the assumption that all scripts under consideration are being produced and then we drop the movie with the largest losses. We continue the iteration until all scripts have positive expected profits. Finally, we draw the taste shocks and calculate ex post locations and profits.

With regard to sequels, we introduce a paramters μ_t that determines the share of scripts that are sequels. In practice, this parameter is calibrated to match the observed revenue share of sequels. For sequels, rather than drawing the location randomly, we select the location from a previous successful (i.e. positive ex post profits) movie.

Using the evolution of country specific market sizes (that is the total box office revenue) throughout the years, we generate year-by-year static simulations and backout a time series for revenue share of sequels for the period under consideration.

3.5.2 Counterfactual: Hollywood without China

To examine the impact of the changing composition of the global movies market we simulate a counterfactual where we keep the market sizes at 2001 levels but feed in the

[6] In practice, we take the observed number of movies and add 60 additional scripts.

calibrated sequel script arrival share. The resulting time series is presented in figure 3.9. Surprisingly but consistent with the profit spaces depicted before, the shifts in market sizes have not induced a higher production of sequels. While these movements did tilt the product supply towards the Asian markets, they did not increase spatial risk and therefore did not shift production towards sequels. Sequels instead must have other benefits that are orthogonal to the between country taste heterogeneity explored here.

3.6 Conclusion

We propose a methodology to estimate taste similarity between countries and estimate a taste space using a newly assembled data on international box office. As an application we investigate how a dramatic change in the movie market structure, namely the increasing importance of Emerging countries for the international boxoffice revenue, can affect the mix of product types, in our case original movies and sequels. We show first, that sequels have a lower production uncertainty and second, that the revenue map has become steeper between 2001 and 2017 because of the change in market structure.

We also simulate the revenue share of sequels once with the actual movie market structure and once holding the market structure constant at the 2001 level. Our current results show only a small influence of market structure on the share of sequels.

Bibliography

Anderson, J. E., S. P., de PALMA, A., and THISSE, J.-F. (1989). Demand for differentiated products, discrete choice models, and the characteristics approach. CORE Discussion Papers RP 824, Université catholique de Louvain, Center for Operations Research and Econometrics (CORE).

Coşar, A. K., Grieco, P. L., Li, S., and Tintelnot, F. (2018). What drives home market advantage? *Journal of International Economics*, 110:135 – 150.

McKenzie, J. (2012). The Economics Of Movies: A Literature Survey. *Journal of Economic Surveys*, 26(1):42–70.

3.7 Appendix

3.7.1 Tables

Table 3.1: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max	P25	P50	P75
Production budget	1009	79.8	55.5	0	300	37	65	110
Total boxoffice	1009	272.1	248.8	52.8	2655.7	115.3	180	323
Profit	1009	192.3	218	-84.2	2418.7	67.1	117.9	227.2
Sequel	1009	.3						

Notes: All variables in $ million. Production budget and total boxoffice from BoxOfficeMojo. Profit is defined as Total boxoffice revenue minus production budget. Sequel is the revenue share of sequels.

Table 3.3: Taste space coordinates regression

	(1)	(2)
	taste dim 1	taste dim 2
PG	-0.0700**	0.00921
	(-2.20)	(0.26)
R	-0.0644*	-0.0219
	(-1.90)	(-0.59)
Nominated	0.0193	0.00886
	(1.30)	(0.55)
Win	0.0000832	-0.0205
	(0.00)	(-1.00)
IMAX	-0.0150	0.0586***
	(-0.74)	(2.66)
Normal Image	0.0336*	-0.0177
	(1.74)	(-0.84)
Sequel=1	-0.0427***	0.00293

	(-3.67)	(0.23)
Runtime	-0.000933***	0.0000302
	(-2.88)	(0.09)
Adventure	-0.0833***	0.0399
	(-3.52)	(1.55)
Animation	-0.149***	-0.0693**
	(-5.40)	(-2.30)
Comedy	-0.0292	-0.0900***
	(-1.24)	(-3.49)
Documentary	-0.0179	-0.121
	(-0.19)	(-1.18)
Drama	-0.0150	-0.0897***
	(-0.59)	(-3.25)
Family	-0.0274	-0.125***
	(-0.79)	(-3.32)
Fantasy	-0.109***	0.0440
	(-3.72)	(1.37)
Foreign	-0.143**	-0.0829
	(-1.99)	(-1.05)
Horror	-0.0722***	0.0537*
	(-2.72)	(1.85)
Musical	-0.142***	-0.0755
	(-2.89)	(-1.40)
Romance	-0.0454	-0.0615

	(-1.08)	(-1.35)
Romantic Comedy	-0.100***	-0.0961***
	(-3.14)	(-2.76)
Sci-Fi	-0.0766***	0.0557*
	(-2.87)	(1.91)
Thriller	-0.000778	-0.0465*
	(-0.03)	(-1.68)
Western	-0.0613	-0.0511
	(-1.05)	(-0.80)
Year FE	Yes	Yes
r2	0.252	0.206
N	981	981

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Regression of taste coordinates on observable movie characteristics: movie rating (PG: parental guidance suggested, R: restricted), Oscar nominated or win, screen format (IMAX, 3D, normal image), runtime in minutes and the genre of the movie.

Table 3.2: Relative Variance of Sequels vs Non-Sequels

	$\sigma^2_{\epsilon,1}$	$\sigma^2_{\epsilon,2}$	N
non sequels	0.23	0.22	755
sequels	0.02	0.04	254

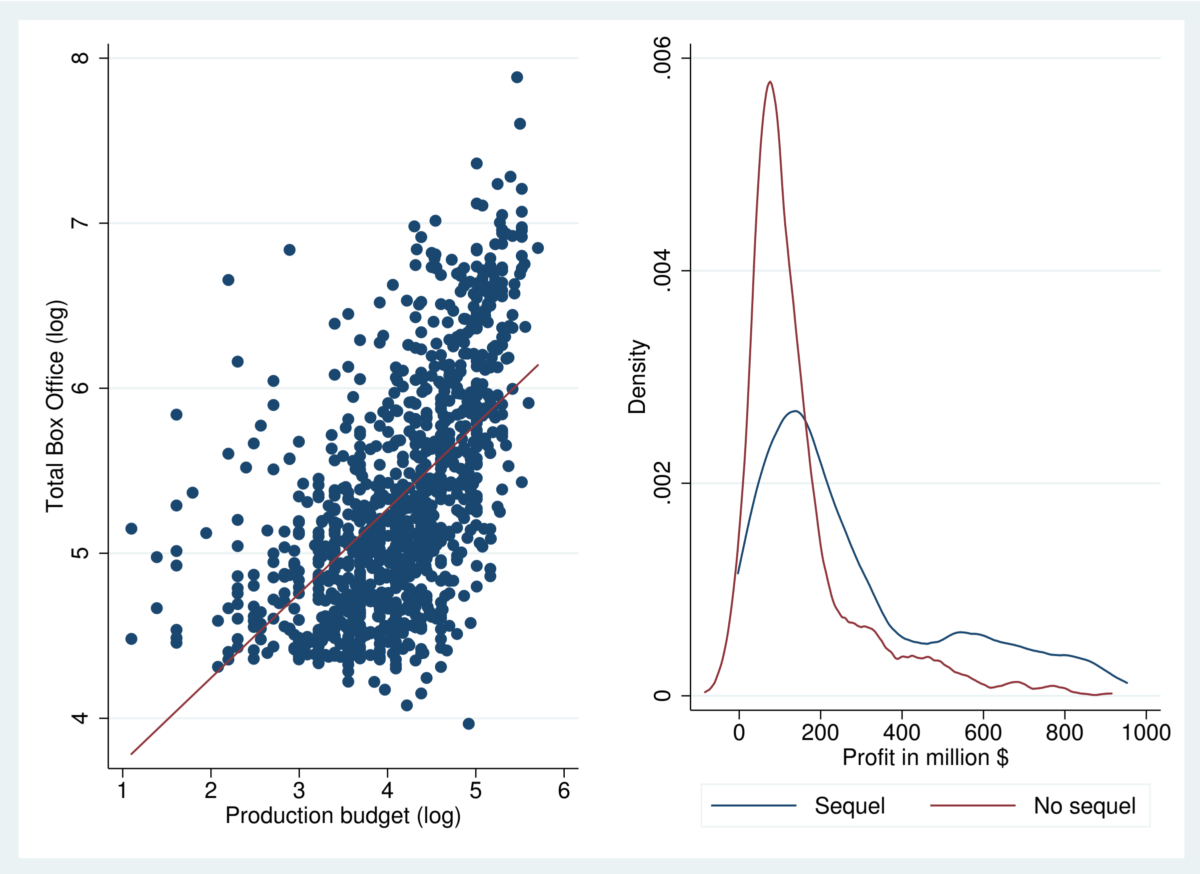
Table 3.4: Sequel compared to prequel

Sequel number:	N	Budget	Revenue	Delta_j
1	81	128	104	97
2	30	151	122	116
3	14	190	137	132
4	8	171	191	147
5	2	350	429	534
6	1	200	125	627

This table shows the median production budget, revenue and estimated delta_j for sequels in percentage of their prequel

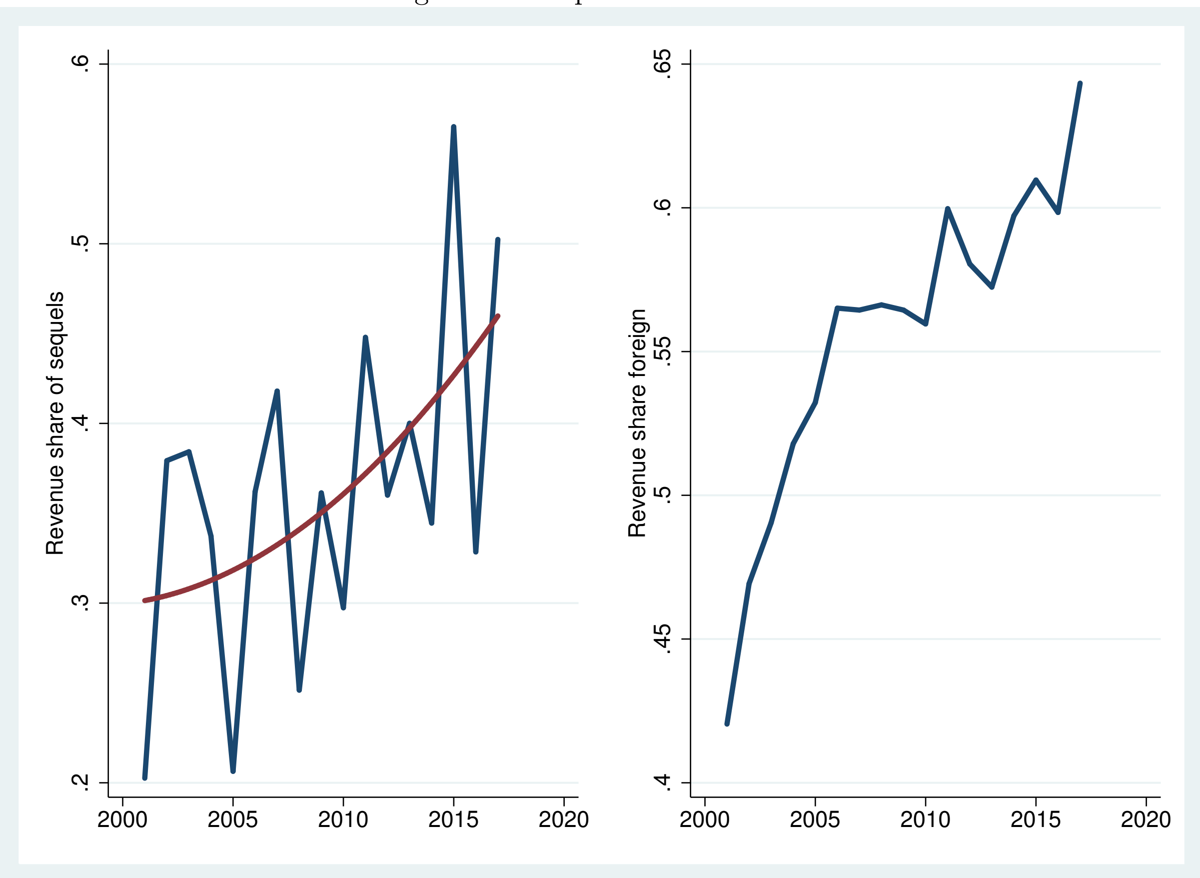
3.7.2 Figures

Figure 3.1: Production Budget and Profitability



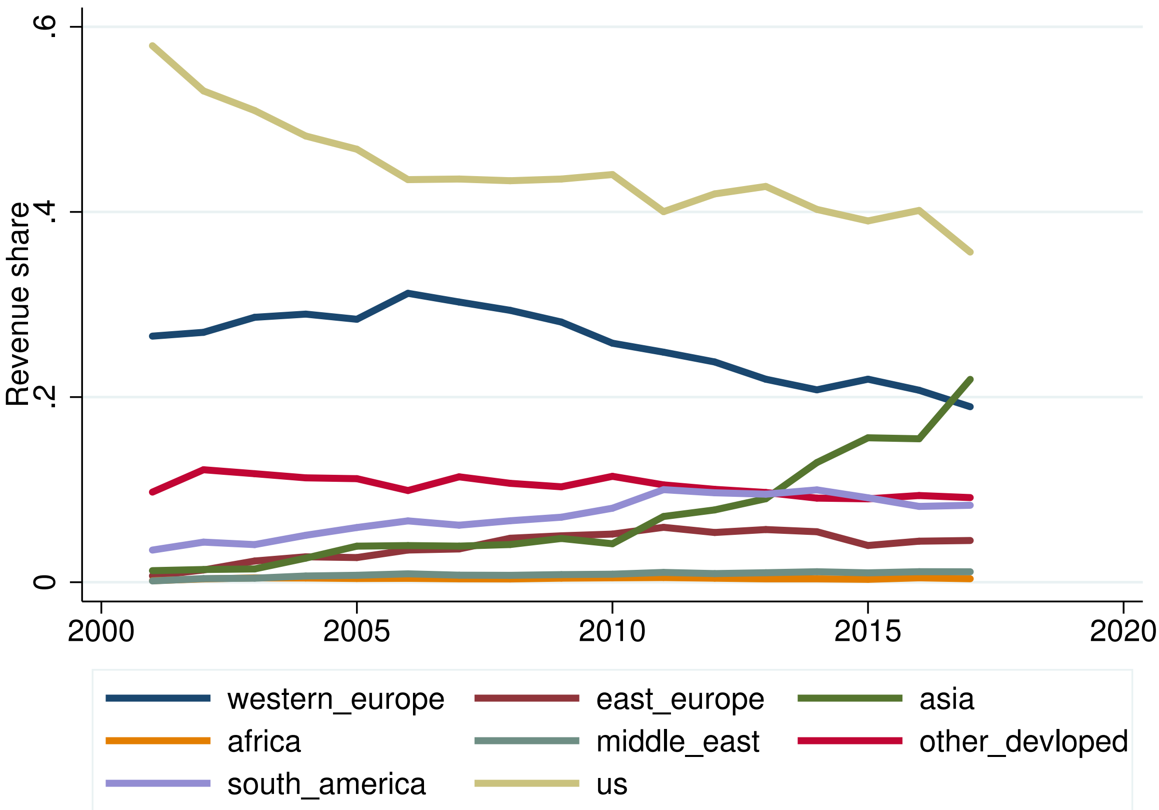
Notes: Left hand side: Relation between log production budget and log total boxoffice revenue with a linear fit in red *Right hand side:* Density of profits for sequels and non-sequels.

Figure 3.2: Sequel Revenue Share



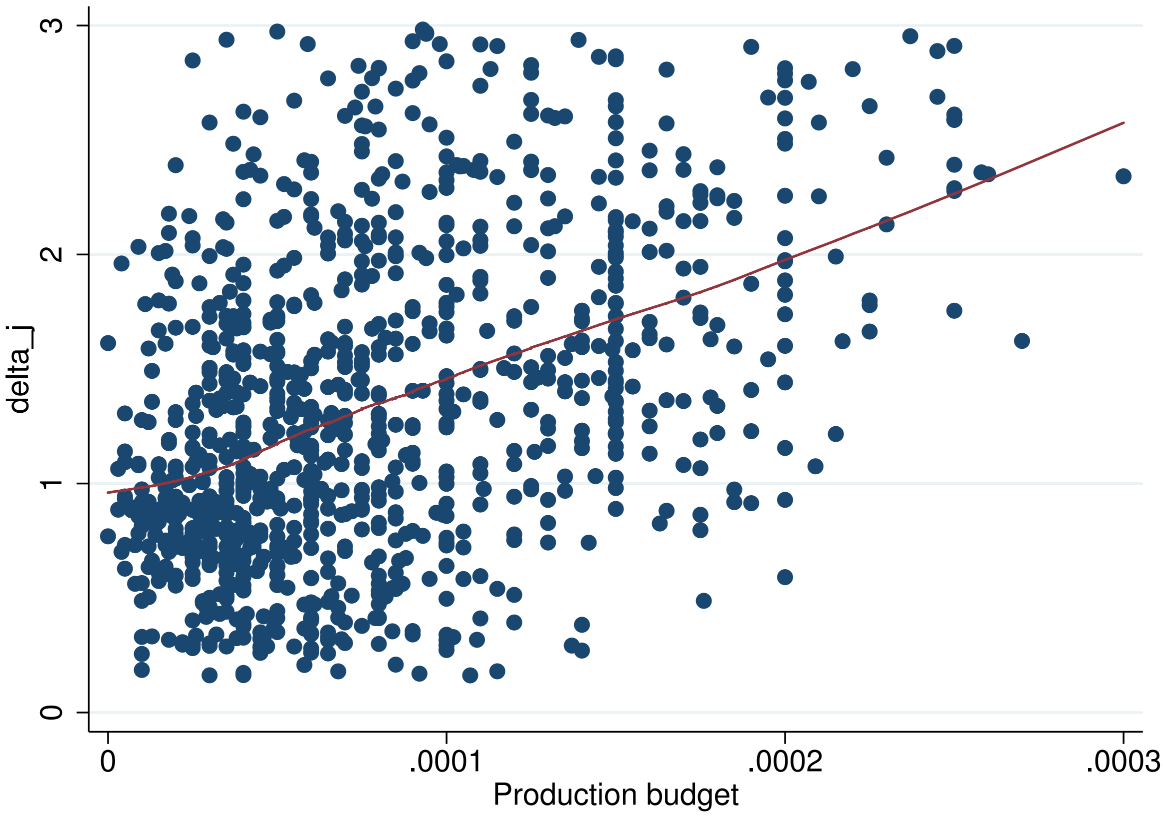
Notes: Left hand side: boxoffice revenue share of sequels *Right hand side:* share of non-US boxoffice revenue in total boxoffice revenue

Figure 3.3: Global Box Office



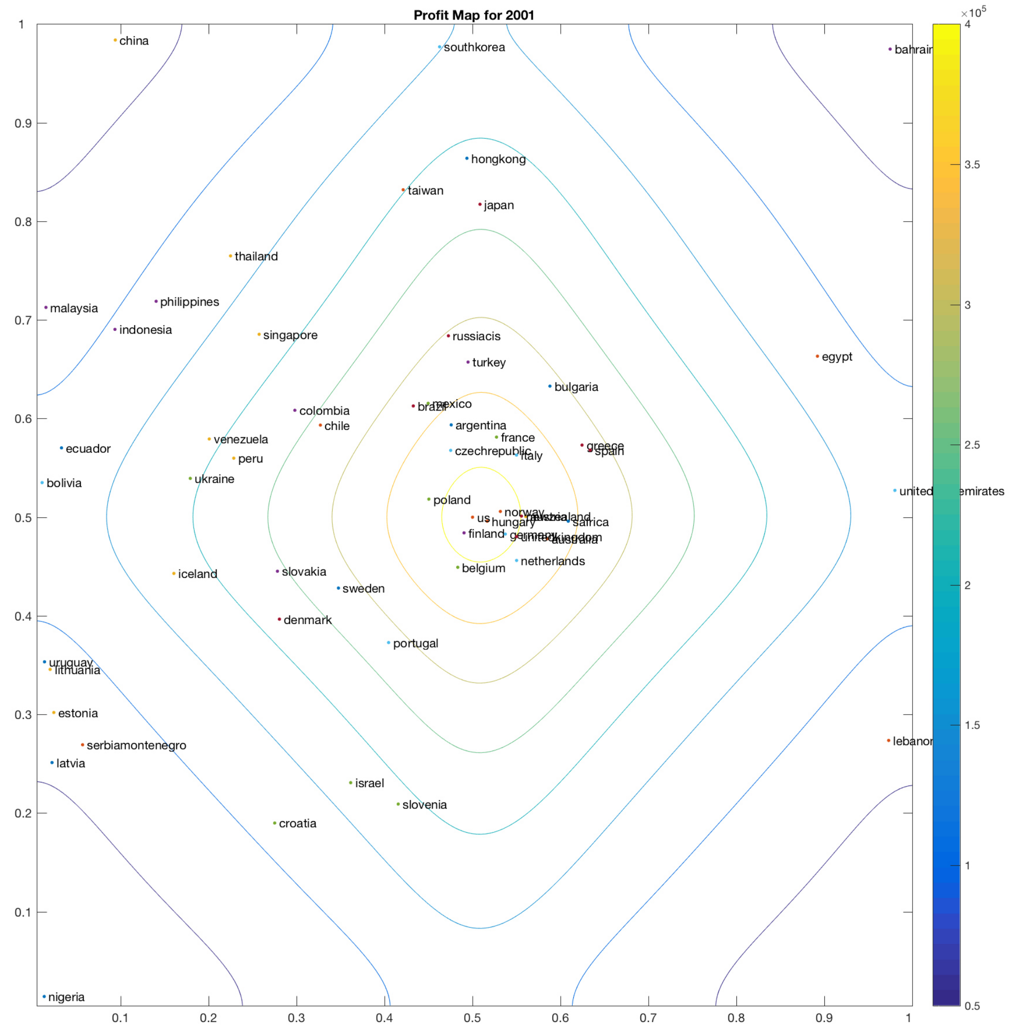
Notes: Share of worldwide boxoffice revenue by region. Other developed countries are: Japan, South Korea, Australia and New Zealand.

Figure 3.4: Production budget and global appeal



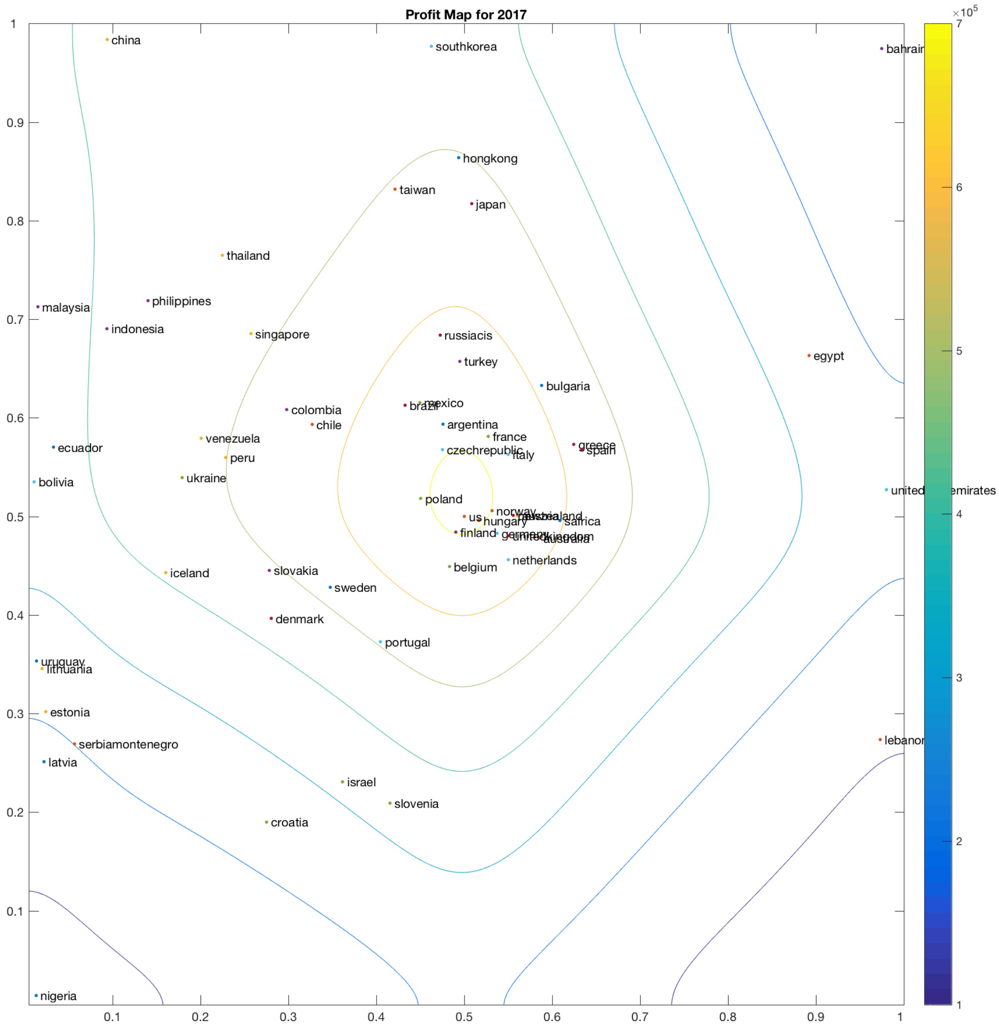
Notes: Relationship between estimate the global appeal of a movie, δ_j and the production budget.

Figure 3.5: Estimated revenue space (2001)



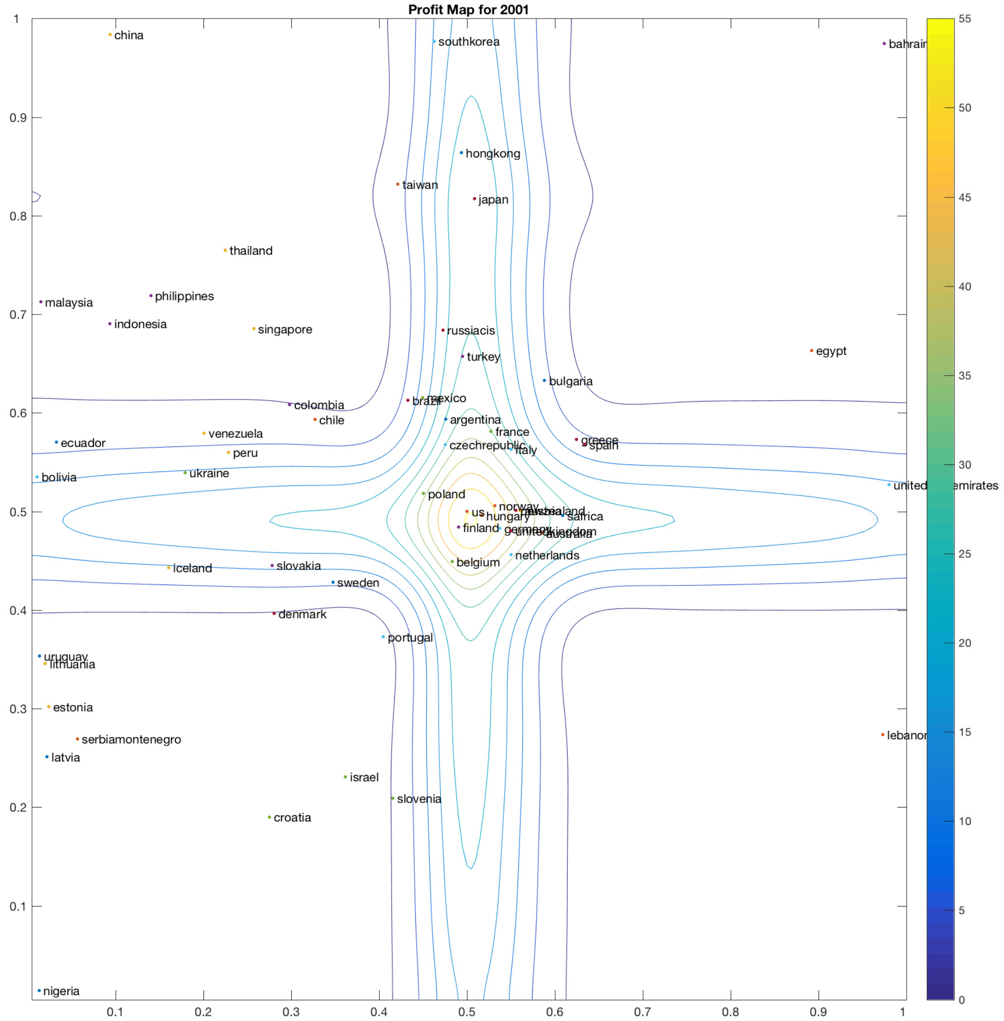
Notes: Revenue map for 2001 in the taste space. Dots are the average taste locations of countries, assumed to be constant over time, relative to the US which is normalized to be at taste position (0.5 0.5). Lines are iso-revenue lines for the year 2001 assuming competitor movies on an evenly spaced grid.

Figure 3.6: Estimated revenue space (2017)



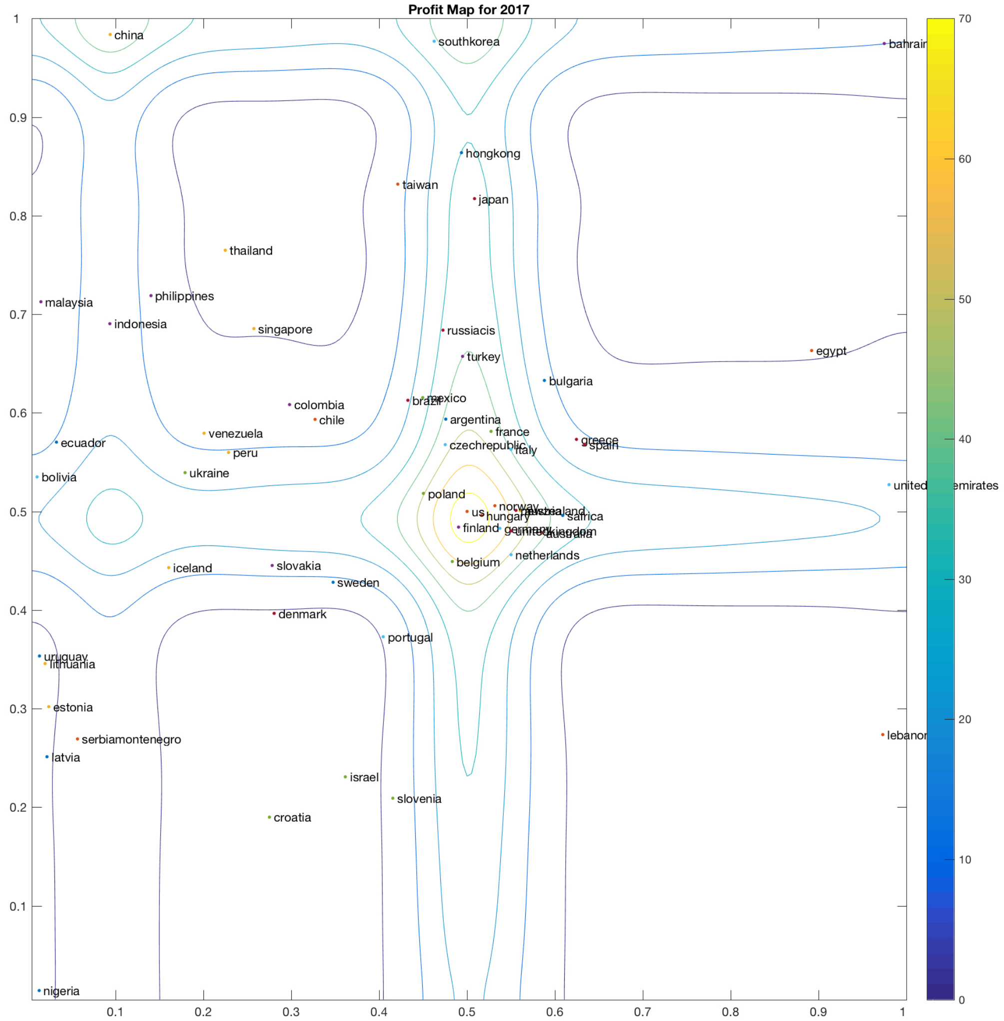
Notes: Revenue map for 2017 in the taste space. Dots are the average taste locations of countries, assumed to be constant over time, relative to the US which is normalized to be at taste position (0.5 0.5). Lines are iso-revenue lines for the year 2017 assuming competitor movies on an evenly spaced grid.

Figure 3.7: Expected revenue: Small vs large variance (2001)



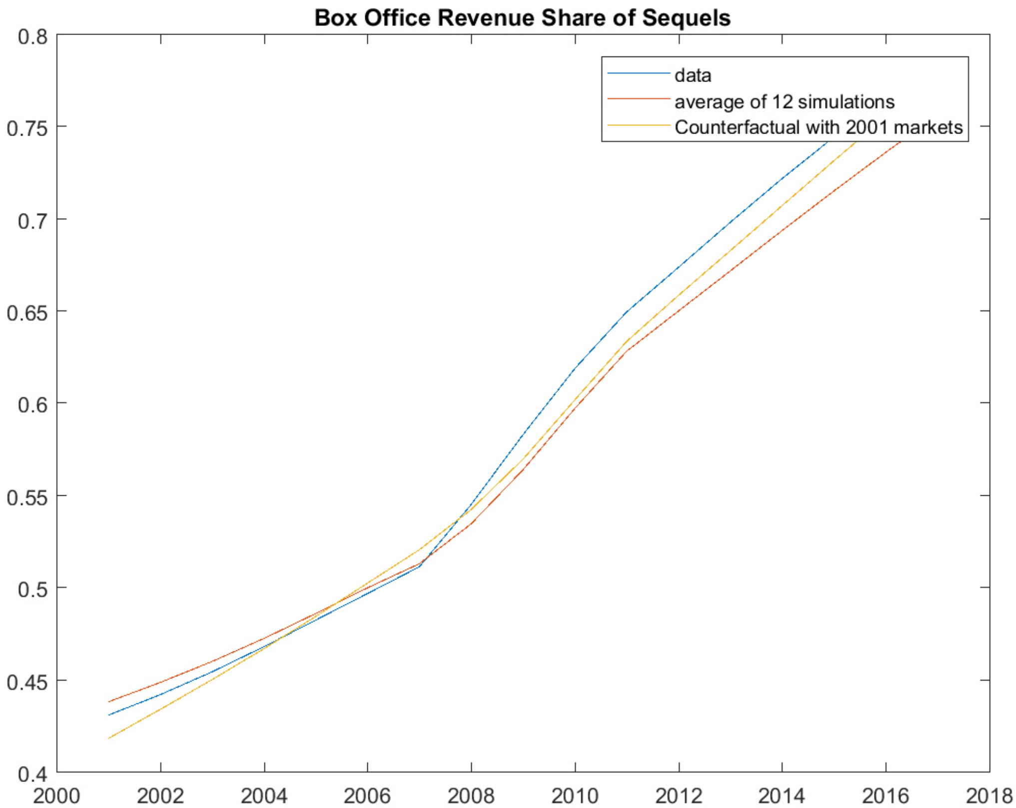
Notes: Revenue map for 2001 in the taste space. Lines represent the difference between the revenue for a movie precisely located at the taste location compared to a movie that faces the risk of a small "taste shock" for the year 2001 assuming competitor movies on an evenly spaced grid. Dots are the average taste locations of countries, assumed to be constant over time, relative to the US which is normalized to be at taste position (0.5 0.5).

Figure 3.8: Expected revenue: Small vs large variance (2017)



Notes: Revenue map for 2017 in the taste space. Lines represent the difference between the revenue for a movie precisely located at the taste location compared to a movie that faces the risk of a small “taste shock” for the year 2017 assuming competitor movies on an evenly spaced grid. Dots are the average taste locations of countries, assumed to be constant over time, relative to the US which is normalized to be at taste position (0.5 0.5).

Figure 3.9: Counterfactual: Sequel revenue share



Notes: Simulation results: The *blue line* shows the smoothed sequel share of total revenue, the *red line* corresponds to the sequel share of total revenue when market structure changes as in the data but using simulated taste locations for movies (average over simulations), the *yellow line* shows the sequel share of total revenue holding the market structure constant at the 2001 level and using simulated taste locations for movies.