Innovation and Corporate Cash Holding in the Era of Globalization*

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Abstract

We document a broad-based trend in rising cash holding 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 (Holström and Tirole, 1998) to show that increased openness to trade can raise the returns to innovation and the demand for cash holding as firms insure against liquidity shocks subject to moral hazard. 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 technological innovation.

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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, mostly in the form of cash.[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 et al, 2017), and indeed there is evidence that the increase in corporate saving and cash holding are closely related (Dao and Maggi, 2017). At the aggregate level, we observe that the corporate sector 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, 2017; IMF, 2017). Understanding drivers of corporate liquidity demand will therefore not only allow us better understand the financing decision of firms, but may 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, the literature on corporate saving and cash holding in the context of recent global trends is still sparse. One salient feature of modern corporations is their growing global exposure and the associated rising 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, potentially due to stronger competition in domestic markets and thus a lower payoff from innovation (Autor et al. 2016); or a positive one (Bloom et al. 2016), possibly due to domestic firms' desire to upgrade their products' quality to gain an edge amid intensifying import competition. In a separate literature in corporate finance, the increase in cash holding has long been documented, and attracted the attention of not only academic researchers, but since recently also the broader public and even led to plans for government intervention.[2] Relative to these two debates, our paper has two main contributions. First, we show in a simple model of liquidity management how the increase in liquid assets holdings is linked to increased R&D spending

[1] Corporate cash holding has been extensively analyzed for the US by a growing literature; see Bates et al. (2009), Pinkowitz et al. (2016), Graham and Leary (2015) to just mention two. 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 efforts of the Korean government to implement a tax on corporate cash stocks in *The Economist*, September 27th 2014.

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 offering a way to reconcile the conflicting evidence from Autor et al. (2016) and Bloom et al. (2016). Second, using firm level data from a sample of G7 countries we find evidence suggesting that export opportunities, and only to a much smaller extent import competition, are the main driver behind the increase in R&D spending and liquid asset holdings.

In our model, the effect of increased trade openness on rising cash holding 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. With investment in innovation being subject to liquidity shocks before the innovation outcome is realized, in the spirit of Aghion et al. (2010), the firm must hold enough liquidity to insure against such cost overrun. 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 stay ”in the game”.

We test the main predictions of the model using firm-level data from Thomson Reuters Worldscope, covering most publicly listed firms in our sample of 5 major advanced economies (US, 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 holding among incumbent firms. Consistent with the model, the impact on cash holding is stronger the larger the firm, both because the less financial frictions it faces, and the more likely it is to export. Importantly, we also observe that spending on R&D activities increases as firms experience more export opportunities, with the effect being stronger for larger and more export-oriented firms. We explore the robustness of these main results by instrumenting for export and import exposure with other countries' export and import intensity to/from China as in Autor et al. (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.

On the theoretical front, this paper combines insights from both modern trade theory (Melitz, 2003), which emphasizes firm heterogeneity in intra-industry trade, as well as 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 strands of theoretical literatures to show that globalization, apart from changing the firm-level and industry-wide productivity, can also lead to systematic shifts in the balance sheets composition and asset demand .

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, that we disentangle the impact of globalization into the channel export opportunities from that of import competition, showing that they differ in important ways. While most papers on the effect of trade and innovation have focused on the import competition channel, Aghion et al. (2017) and Coelli et al. (2017) are two other studies that have also considered the export market channel. Second, to the best of our knowledge, ours is the first paper to link the trend in globalization-induced innovation with shifts in corporate liquidity demand.

Given the connection to corporate liquidity, our paper builds on a large volume of work in empirical corporate finance that examine patterns and determinants of cash holding, primarily of public firms in the US (e.g. Bates et al. 2009, Pinkowitz et al. 2016). In Lyandres and Palazzo (2016) and Ma et al. (2017), cash holding and innovation are linked through a strategic motive. High cash holding can deter potential competitors in innovation and consolidate first mover advantage in product markets. Similar to our paper, Falato et al. (2014) also attribute the rise in cash holding in the US 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, and instead, relate the need for cash holding to the low collateralizability of intangible assets. In our model, the motive for cash holding 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

[3]Other motives for cash holding and corporate saving, less related to our paper's channel, have also found

organized as follows: section 2 presents some key stylized facts regarding cash holding, innovation intensity and globalization. Section 3 introduces a model linking the expansion of export opportunities with the firm's decision to invest in innovation and its implication for cash holding. Section 4 then outlines the empirical strategy and tests key prediction of the model. Section 5 concludes.

2 Stylized facts

The increase in corporate cash holding is not only a US phenomenon. Figure 4 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 US 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, IMF, 2006), suggesting that the rise in cash stock has been financed primarily 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 US corporate sector during the past decade (Falato et al., 2013). While less is known for other countries other than the US, 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 5).

Moreover, the two trends are not unrelated, as becomes evident in the cross-sectional differences in cash holding trends. Figure 6, 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

support in the literature: e.g. Foley et al. (2007) and Armenter and Hnatkovska (2017) for tax motive, Azar et al. (2016) for cost of carry, Dittmar et al. (2003) for corporate governance motives.

cash ratio has been most pronounced, as e.g. in the US 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 holding for innovating firms suggest that the decision to innovate and that over the optimal level of cash holding are closely related.

There is evidence that the changing composition of firms in the US has increased the average cash ratio, as younger cohorts of firms launching IPO have been entering the sample with higher cash holding 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 7 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, 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 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 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).

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

with the superscript I designating the corresponding variable (cash stock CH and total assets A) of incumbent firms. Figure 8 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 2010, it has also been the intensive margin, that is, the cash evolution within firms, that has driven the overall increase.

3 A model of liquidity demand and trade-oriented innovation

Motivated by the preceding stylized facts, in the following, we present the main elements of a model that links the decision of 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. Alternatively, globalization intensifies import competition, threatening the less productive firms, hence also widening the profit differential between the most and least productive firms. Both aspects of globalization thus increase incentive for domestic firms to innovate and move up in the productivity distribution. 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.

3.1 Model set-up

The framework is a 3-period model combining motive for cash holding 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 has available assets A and decides whether to invest in innovation to upgrade its productivity to a higher level $\phi \geq \phi_0$ at fixed cost I, where $I > A$ so that the firm has a borrowing need. 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.

Upon surviving the liquidity shock, the firm reaps the benefit of its 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. However, 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 minimum productivity level ϕ_0 (see Figure 1). In addition, since shirking is not verifiable ex-post, the firm gets to keep private benefit B regardless of the actual productivity realization, subjecting the innovation project to moral hazard.[4]

After drawing the new productivity, in either case, 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.

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 draw-

[4] 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.

ing productivity ϕ, the firm's profit as a function of productivity is given by its profit in domestic and export markets (see derivation in Appendix):

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

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:

$$\phi_X^* = \tau \left(\frac{f_x}{M^X}\right)^{\frac{1}{\sigma-1}} \tag{2}$$

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

$$E(\pi) = \int_{\phi_0}^{\infty} M\phi^{\sigma-1} g(\phi) d\phi + \int_{\phi_X^*}^{\infty} \left[M^X \left(\frac{\phi}{\tau}\right)^{\sigma-1} - f_X\right] g(\phi) d\phi \tag{3}$$

Applying the properties and parameters of the Pareto distribution and normalizing $\phi_0 = 1$, we can solve for expected profit (if the firm does not shirk) to be:

$$E(\pi) = \frac{M\kappa}{\kappa - \xi} + \frac{\kappa f_x}{\kappa - \xi} \phi_X^*(f_x, \tau)^{-\kappa}, \tag{4}$$

where we have $\frac{\partial E(\pi)}{\partial \tau} < 0$. With lower trade costs, 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.

We now move one step back to the moral hazard stage, that is, after the firm has survived the liquidity shock but before it draws the new productivity. 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 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:

$$\eta \geq \eta_{min} = \frac{B/A}{\frac{\kappa}{\kappa-\xi} - \frac{\lambda}{\lambda-\xi}} \tag{5}$$

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.[5]

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 restricts the set of viable values for I), the firm will want to innovate and require external funding $I - A > 0$ 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?

3.2.1 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, by specifying the liquidity cutoff level ρ^*, which also corresponds to the firm's level of cash holding, and the fraction of profit left for the firm η:

$$max_{\rho^*,\eta} \int_0^{\rho^*} E_G(R_f) f(\rho) d\rho - A \tag{6}$$

[5] 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 holding ρ^* even more.

subject to:

$$\int_0^{\rho^*} \left[E_G(\pi) - E_G(R_f) - \rho\right] f(\rho) d\rho = I - A \tag{7}$$

$$E_G(R_f) = \eta E_G(\pi^D) \tag{8}$$

$$\eta \geq \eta_{min} \tag{9}$$

The solution of this maximization problem is outlined in the Appendix and follows closely Tirole (2006). To implement the optimal contract, the lender invests the amount $I - A + \rho^*$ in the firm and require it to hold ρ^* in liquid form by means of a liquidity covenant (see Holmström and Tirole, 1998). We establish the following main results.

Result 1 *Only firms with sufficiently strong balance sheets can innovate. Innovating firms hold more cash than similar non-innovating firms. Innovating firms with stronger balance sheets hold more cash.*

This result is due to the fact that more initial assets reduce the pledgable income necessary to induce lenders to invest (as firms can rely more on self-financing) and all else equal, increases the chance of a firm innovating. As shown in the Appendix, the firm will not be able to obtain funding and innovate if its initial asset A is below the minimum level $I - P(\rho^0)$, where $P(.)$ is the pledgable income as a function of the cutoff, maximized at $\rho^* = \rho^0 = E_G(\pi) - \eta_{min} E_G(\pi^D) < \rho^1$. When initial assets are in the range $I - P(\rho^0) \leq A < I - P(\rho^1)$, the optimal cutoff ρ^*, i.e. the cash holding of the firm resulting from the optimal contract with the investor will be determined by the break-even condition of the lender:

$$P(\rho^*) = F(\rho^*)\left[E_G(\pi) - \eta_{min} E_G(\pi^D)\right] - \int_0^{\rho^*} \rho f(\rho) d\rho = I - A. \tag{10}$$

Call the level of the cutoff solving this condition to be $\rho^* = \tilde{\rho}$. If initial asset level is even higher, i.e. $A > I - P(\rho^1)$, then the optimal cutoff equals the first-best value $\rho^* = \rho^1 = E_G(\pi)$. It further follows that $0 < \rho^0 < \tilde{\rho} < \rho^1$. That is, compared to similar (same ϕ) but non-innovating firms, the cash-holding of innovating firms is always higher ($\rho^* > 0$). Moreover, the probability of innovating as well as level of cash holding and hence the probability of reaping the long-term benefits of innovation are both increasing in the strength of the firm's balance sheet A.

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 holding, that is $\frac{\partial\rho^*}{\partial\tau} < 0, \frac{\partial\rho^*}{\partial M^X} > 0$ and its expected spending on innovation $I + \int_0^{\rho^*} \rho f(\rho)d\rho$.*

Recall that cash holding of the innovating firm equals $\rho^* = \rho^1 = E_G(\pi)$ if it has high assets $A \geq I - P(\rho^1)$. In this case, it immediately follows that $\frac{\partial\rho^1}{\partial\tau} < 0$ as lower trade costs increase expected profits from innovating by increasing the probability of becoming an exporter (through lower exporter cutoff ϕ_X^*) and increasing profit from exporting conditional on drawing a high enough productivity. If the firm has assets in the intermediate range $I - P(\rho^0) \leq A < I - P(\rho^1)$, then by implicit function theorem applied to the optimality condition (10), we also obtain $\frac{\tilde{\rho}}{\partial\tau} < 0$. Hence, conditional on being an innovator, i.e. on having sufficiently high A, the level of cash holding always increases with lower trade costs τ (or similarly, with higher export demand M^X). Finally, since a higher ρ^* allows the firm to withstand more innovation-induced liquidity shocks, total expected spending on innovation $I + \int_0^{\rho^*} \rho f(\rho)d\rho$ also increases (as the upper integral limit shifts up).

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

As discussed in Result 1, the asset 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) and (4). This increases the cutoff level $\rho^0 = E_G(\pi) - \eta_{min}E_G(\pi^D)$ which maximizes the pledgable income and thus the maximum pledgable income itself as $\frac{\partial P(\rho^*)}{\partial\rho*} > 0$ for $\rho^* \leq \rho^0$. As more income can be pledged, the minimum asset level $I - P(\rho^0)$ for firms to obtain funding to innovate is lowered. If the distribution of initial asset level A is taken as exogenous in each industry, lower trade costs increases the share of firms that innovate and, as these firms have higher cash holding than non-innovating firms by the amount $\rho*$, also increases the average cash holding in the industry.

All three results regarding the schedule of optimal cash holding for innovation as a function of the initial asset, the set of innovating firms and all shifts triggered by more trade openness (through lower trade costs and/or larger markets) are depicted in Figure

3.

3.3 Testable implications

In the following, we discuss measurability of some key variables in the firm-level data and spell out the model's main testable hypotheses.

First, the level of initial assets A is critical for many of the model's results. In theory, as argued by Tirole (2006), A stands for any available source of funding or collateral (liquid or illiquid) that the firm can use as down-payment for its investment project. In a strict sense, it should correspond to net worth of the firm, which measures the effective external debt capacity. So if we think of firms in the model as starting out in $t = 0$ with similar size (measured by assets or employment), and reflected in their initial sales and profit $\pi(\phi_0)$, some of them will have higher net worth than others.

Secondly, we understand innovation here as any activity that requires long-term financial commitment and exposes the firm to liquidity risk in the interim. R&D activities are one category of such innovation activities, but so is any other activity of the firm that increases its intangible asset, 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 and pension costs, and furthermore is missing for a larger set of firms than $R\&D$ spending. We therefore restrict ourselves to $R\&D$ as a measure of innovation activity in the empirical analysis.

Given these data constraints, the main testable predictions of the model are the following:

- For the within-firm variation in cash holding, Result 1 and Result 2 predict that a firm's cash holding should only increase with export opportunities if the firm has high enough net worth or borrowing capacity (parameter A in the model). Using size as a proxy for a firm's borrowing capacity or credit constraint, we should see that the marginal impact of trade openness on cash holding is stronger the larger the firm. As not all firms export and our model prediction at the intensive margin only applies for firms above the exporter cut-off, we should observe the impact of increased trade openness to be stronger the more export-oriented is the firm. In the Worldscope dataset, the variable closest to exporter status is the share of foreign sales (which includes exports and sales by foreign subsidiaries in case of multinationals). As exporting and multinational firms tend to be those that innovate, have high intangible capital and a high share of non-production workers (Bernard et al., 2007) we should observe a stronger effect of expanding export opportunities on the cash holding and innovation activity of these firms.

- Result 2 predicts that, if the firm has high enough net worth, the increase in cash holding facilitates more innovation activity by making firms more able to absorb liquidity shocks in the interim. Measured spending on innovation (equal $I + \int_0^{\rho^*} \rho f(\rho) d\rho$ in the model) will therefore also increase with expanding export opportunities.[6] Similar to the result for cash, this positive effect should be stronger for larger (or higher net worth) firms, and firms which are more open to trade.

- At the industry-level within a country, Result 3 implies that cash holding 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 net worth or borrowing capacity. 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 signify either a non-reporting of actual spending or zero spending on $R\&D$.[7] We therefore focus on the intensive margin of innovation and associated cash holding (Results 1 and 2)

[6]Note that this prediction applies to spending on innovation, not necessarily its outcome or quality.
[7]This is a well-known limitation of firm-level $R\&D$ data, see e.g. XXXX.

in the empirical analysis below.

4 Empirical Analysis

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 US, 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 1 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 more than 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.[8] Consistent with the stated focus on the intensive margin of innovation and cash holding within firms, we limit most of the analysis below to firm-year observations with non-missing $R\&D$ spending.[9]

Although the dataset contains consolidated accounts of mostly publicly listed firms, in related work, we confirm that the combined cash holding 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 (Dao and Maggi, 2017). This finding on aggregate representativeness is consistent with other studies focusing the US corporate sector, which also established that the corporate net lending and cash holding is extremely concentrated among large firms (see Armenter, 2012 and references therein). Understanding drivers of cash holding and saving by listed firms can therefore shed light

[8] While we have almost 200.000 firm-year observations over which these summary statistics are computed, in the following, the sample is greatly reduced when we seek to compute a firm-level measure of exposure to export and import.

[9] Our main findings broadly hold when we set missing $R\&D$ spending to zero as often done in the literature.

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 different industry classifications for each firm: a static four-digit SIC code for the primary product in a reference year, and a second classification which are multiple (usually 2) time-varying product segment SIC codes, accompanied by the amount of sales of each product category. Using an initial year's product segment sales shares, we 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 and MFN tariff data come from the UN Comtrade database and TRAINS database, respectively, both of which are then matched to the SIC code of each firm in an initial year to derive firm-specific weighted exposure to export and import shocks (more details below).

Figure 9 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 10 describes the extent of tariff liberalization in our sample economies and their trading partners. It is worth noting that tariff liberalization has been stagnant over the last two decades in sample countries mainly because their tariff rates have already reached low levels. On the contrary, their trading partners, 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 underlines the importance to look at both the export and import margins when analyzing the effect of trade.

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 holding more for a given innovating firm with high borrowing capacity. Moreover, the model suggests that it occurs through boosting incentive for innovation, ultimately resulting in an increase in innovation spending.

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

$$Y_{ict} = \beta^{exp} SHOCK^{exp}_{ict-1} + \beta^{imp} SHOCK^{imp}_{ict-1} + \Theta Z_{ict-1} + FE + \varepsilon_{ijt},$$

where Y_{ict} is the dependent variable of interest, such as a measure of cash holding or innovation spending for firm i in country c and year t. $SHOCK^{exp}_{ict}$ captures a firm's potential export opportunities that could stem from, for instance, improved market access or increased demand abroad. Likewise, $SHOCK^{imp}_{ict}$ denotes the degree of import competition experienced by a firm. As such, export and import shocks are separately estimated. Z_{ict} 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 and sector-year fixed effects absorb any other macroeconomic or sectoral factors that could affect a firm's cash holding or innovation spending decisions.

As spelled out above, the model predicts that the effect of globalization should be more pronounced for firms with high enough borrowing capacity to undertake innovation-related investment. This can be tested by including additional interaction terms to capture heterogeneous responses along different levels of borrowing capacity proxied by, for instance, total assets, net worth, or interest coverage ratio. Specifically, we assign each firm a tercile dummy variable encoding its relative position in the distribution of respective proxy measure in a given country and year. The corresponding specification can be expressed as:

$$Y_{ict} = \sum\nolimits_{k=exp,imp} \left[\beta^k SHOCK^k_{ict-1} + \sum\nolimits_{j=2,3} \beta^k_j SHOCK^k_{ict-1} * I_{ict-1,j} \right] + \Theta Z_{ict-1} + FE + \varepsilon_{ijt},$$

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

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 minimizing such concerns—beyond taking one-year lagged terms—, among several possible candidate variables for $SHOCK^{exp,imp}_{ict}$, we propose measures of exports to, and imports from, China, both at the country-industry level as a measure for export opportunities and import competition, respectively. 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 partner country. Specifically, we construct the firm-level measure of export opportunities as the weighted average of such country-industry level shocks:

$$SHOCK_{ict}^{exp} = \sum\nolimits_{s} \omega_{ic}^{s} \left(ChinaExport\right)_{cst},$$

where $\left(ChinaExport\right)_{cst}$ is calculated as the ratio of exports to China in total exports in industry s of country c in year t. This country-industry level measure is converted to a firm-level one using weights ω_{ic}^{s} which correspond to the respective share of a given firm's sales in each industry in the initial year. Similarly, the firm-level degree of import competition is constructed as:

$$SHOCK_{ict}^{imp} = \sum\nolimits_{s} \omega_{ic}^{s} \left(ChinaImport\right)_{cst},$$

where $\left(ChinaImport\right)_{cst}$ is calculated as the ratio of imports from China in total imports in industry s in country c in year t. The firm-level measure is constructed from a weighted average of industry measures, with weights ω_{ic}^{s} defined as above.

Still, however, we acknowledge that such measures are not entirely immune to potential endogeneity biases. We thus follow Autor, Dorn, and Hanson (2013) and further instrument export shares to China from a given country and import shares from China to a given country (where the firm is incorporated) with the corresponding average values to and from 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.[10] Such China-specific shocks common to all third partner countries should therefore be strongly correlated with the change in export opportunities and import competition facing firms in a given partner country, but not be directly related to their cash holding and innovation spending once their overall performance and other

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

macroeconomic as well as industry specific shocks are controlled for.

Past evidence, as discussed in detail in Autor, Dorn, and Hanson (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.[11] Therefore, we will also check the robustness by employing alternative trade shock measures using MFN tariff rates whereby a weighted average of MFN rates across trading partner countries constitutes country-industry level export shock measure while a given country's MFN rates measure import shock.

4.3 Estimation Results

4.3.1 Globalization and cash holding

Table 2 and Table 3 present firm-level estimation results from our baseline specification by 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, net worth, and interest coverage ratio, respectively.

A first look at OLS estimation results in Table 2 suggests no significant effect from expanded export opportunities or import competition on average. As we add interaction terms with tercile dummy variables, however, smaller firms (column 2) or low net worth firms (column 3) are found to experience negative effects from export shocks on cash holding, whereas bigger firms or high net worth firms see positive effects from export shocks on cash holding, which is in line with our model predictions. On the other hand, the estimation using interest coverage ratio as a proxy for borrowing capacity shows opposite results (column 4). As for the effect of import shocks, no differential results are found across each

[11] For example, if it was correlated productivity shocks across sample countries that drove growth in imports from (exports to) China, our estimated effect for imports (exports) is likely to be a lower-(upper-)bound of the true effect.

segment of firms in terms of asset size, net worth level, or intrest coverage ratio (columns 2-4).

Turning to Table 3 for 2SLS estimation results, the bottom panel summarizes the first stage regression results whereby the substantial predictive power of instrumental variables from the peer country group for a given country's export and import shocks is confirmed. The second stage regression results in the upper panel further reveals that coefficient estimates from 2SLS estimator tend to be greater than those from OLS estimator in absolute terms, and also more precisely estimated with higher statistical significance levels. This suggests that our instrumental variable strategy could partly correct measurement errors in trade shock variables. Specifically, while 2SLS estimator yields, on average, no significant effects from export and import shocks (column 1) similarly to OLS estimator, evidence supporting our model's prediction—potential heterogeneity in the degree of response to globalization shocks— is more pronounced in 2SLS estimation results (columns 2-4).

Figure 11 illustrates this differential by plotting the reduced-from 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 reduced form corrleation is only small and statistically insignificant for firms in the bottom tercile of the asset size distribution, it is positive and highly statistically significant for the top tercile firms. To the extent that firm size is a valid proxy for the degree of borrowing capacity, such heterogeneity in the degree of the export channel on cash holding is consistent with the model. Similarly, firms with highest net worth or interest coverage ratio increase cash holding as they face positive export shocks, but firms with lowest net worth or interest coverage ratio reduce cash holding (columns 3 and 4 in Table 3). Note that the regressions control for firm, sector-year, country-year fixed effects as well as sales and operating cash flows so that the impact on cash holding is not mechanically driven by increased profitability, nor other economy-wide and industry-wide trends.

The size of the estimated coefficient is such that a 1 percentage point increase in export opportunities to China raises cash-to-asset ratio by around 6 percent more for firms with highest borrowing capacity than those with lowest borrowing capacity who actually reduce cash-to-asset ratio by around 4 percent, conditional on all other industry-wide and macroeconomic factors affecting cash holding proportionately across firms. Given the observed median values for export shocks and cash-to-asset ratio in the sample, a back-of-the-envelope calculation suggests that around 15-35 percent of the total increase in cash holding in larger firms over the last decade could be explained by globalization-led growth in export opportunities. On the other hand, the import channel yields much smaller and nosier estimates, which do not vary systematically by firm size or net worth, possibly reflecting offsetting forces of increased foreign competition on innovation activity as in Aghion et al. (2005).

4.3.2 Globalization and R&D Investment

Next, we turn to testing the underlying mechanism of the model: firms raise cash holding because of an increased incentive for R&D investment in response to globalization shocks. This implies that an increase in cash holding would be translated to an increase in R&D spending. To test this, we replace the dependent variable in the specification above with R&D spending in log (multiplied by 100 for ease of interpretation).

Table 4 and Table 5 present the estimation results from our baseline specification using OLS and 2SLS estimator, respectively. Both OLS and 2SLS estimation results confirm previous cash results in that there is no strong average effect of globalization shock on innovation spending (column 1 in Tables 4 and 5). However, underlying heterogeneity across firms is consistent with the model's prediction. As we introduce interaction terms between globalization shock measures and firm-level characteristics as before, 2SLS estimation results confirm the presence of significant and sizable export channel effects particularly for bigger, higher net worth, or higher interest coverage ratio firms, whereas firms with lower borrowing capacity actually reduce their R&D investment in response to globalization shocks (columns 2-4 in Tables 5).

Thus far, our results have shown that firms respond to globalization shocks—especially those associated with expanding export opportunities—by raising cash holding, and that this effect is consistent with stronger incentives for R&D Investment. Moreover, our results confirm that such patterns tend to hold more strongly for bigger firms, firms with higher net worth, or those with higher interest coverage ratio. 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 associated with growing globalization can therefore explain part of the recent increase in corporate cash holding worldwide.

4.4 Other robustness checks and placebo tests

In this section, we check the robustness of our main findings along various dimension. First, we employ alternative globalization 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 in its two main product segments. A decrease 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 on cash holding from such alternative measures using MFN tariff rates are summarized in Table 6. Consistent with the baseline results using the China trade shock, we also find that a decline in export tariffs faced by firms is associated with higher cash holding for firms in the top tercile of the borrowing capacity in each country, but lower cash holding for firms in the bottom tercile, particularly, although the estimates are nosier when borrowing capacity is proxied by interest coverage ratio (column 4). Once again, the impact is stronger through the export expansion rather than the import competition channel. Likewise, estimation results on $R\&D$ spending summarized in Tables 7 confirm the robustness to alternative globalization shocks measures using MFN tariff rates: a fall in export tariffs induces a firm to increase its spending on $R\&D$ particularly more for firms with higher borrowing capacity—proxied by total assets or net worth—, while there is no statistically significant effect of falling import tariffs.

Noting that previous studies mostly focused on US firms where tax motive is proposed to be a major determinant of an increase in cash holding, we check the possibility that our main findings are somehow driven by such factors perculiar to US firms, simply by excluding US firms in our sample. Estimation results reported in Tables 8 and 9 show that our results are quite robust to excluding US firms, suggesting that our main findings did not merely reflect other potential mechanisms unique to US firms.

Lastly, we conduct a placebo test by restricing the sample to non-innovating firms that have never reported R&D spending. Since our mechanism highlights the demand for cash through R&D activity, we should expect our main findings not to hold in this non-innovating firms sample. This is exactly what we find in Table 10 where there is no significant effects from export or import shocks across all types of firms.

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 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. Given that the trends in technological advancement and globalization will continue unabated, our paper's findings imply that the demand for liquid assets may increase as well, possibly exerting downward pressure on real interest rates and entrenching the high corporate saving rate across the industrialized world.

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A Appendix

A.1 Deriving the expected profit from innovating

A.1.1 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.

A.1.2 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:

$$E(\pi) = \int_{\phi_0}^{\infty} M\phi^{\sigma-1} g(\phi) d\phi + \int_{\phi_X^*}^{\infty} \left[M^X \left(\frac{\phi}{\tau}\right)^{\sigma-1} - f_X\right] g(\phi) d\phi \tag{11}$$

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 (11), and normalizing $\phi_0 = 1$, we obtain:

$$E(\pi) = \frac{M\kappa}{\kappa - \xi} + \frac{\kappa f_x}{\kappa - \xi} \phi_X^*(f_x, \tau)^{-\kappa}, \tag{12}$$

which is equation (4) in the text.

A.2 Solving for the optimal contract

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

$$max_{\rho^*,\eta} \int_0^{\rho^*} E_G(R_f) f(\rho) d\rho - A \tag{13}$$

subject to:

$$\int_0^{\rho^*} \left[E_G(\pi) - E_G(R_f) - \rho\right] f(\rho) d\rho = I - A \tag{14}$$

$$E_G(R_f) = \eta E_G(\pi^D) \tag{15}$$

$$\eta \geq \eta_{min} \tag{16}$$

The financing market is perfectly competitive, so that expected returns for the lender is zero, which is the first constraint in equation (14). Substituting this constraint and the payout rule (15) into the objective function of the firm, we can reformulate the problem to:

$$max_{\rho^*,\eta} \int_0^{\rho^*} \left[E_G(\pi) - \rho\right] f(\rho) d\rho - I = max_{\rho^*,\eta} \left\{ E_G(\pi) F(\rho^*) - \int_0^{\rho^*} f(\rho) d\rho - I \right\} \tag{17}$$

subject to the break-even condition (14) and the incentive compatibility (IC) condition (16).

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

$$E_G(\pi)f(\rho^*) - \rho^* f(\rho^*) = 0, \tag{18}$$

that is when the cut-off is at the first-best level $\rho^* = \rho^1 = E_G(\pi)$. However, this cut-off is only feasible if it satisfies the lender break-even constraint (14), in other words, if the maximum pledgable income P, given by:

$$P(\rho^1) = F(\rho^1)\left[E_G(\pi) - \eta_{min} E_G(\pi^D)\right] - \int_0^{\rho^1} \rho f(\rho) d\rho \tag{19}$$

is at least as large as the initial outlays $I - A$ for the lender. This is the case if:

$$A \geq I - P(\rho^1) \tag{20}$$

In this high-asset scenario, substituting ρ^1 into the break-even condition (14) delivers the equilibrium η, which can be shown to fulfill the IC constraint (16).[12]

If the initial asset condition (20) is not satisfied, then the first-best cut-off cannot be implemented and the optimal liquidity level ρ^* is strictly lower than first best. This follows immediately from the fact that pledgable income $P(\rho^*)$ is decreasing in ρ^* and that ρ^1 already maximizes (17). Moreover, as the pledgable 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 $\tilde{\rho}$ is then pinned down by the break-even condition, that is, it is implicitly given by:

$$\int_0^{\tilde{\rho}} \left[E_G(\pi) - \eta_{min} E_G(\pi^D) - \rho\right] f(\rho) d\rho = I - A \tag{21}$$

or:

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

Finally, if initial assets are too low, such that the maximum pledgable 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:

$$A < I - P(\rho_0, \eta_{min}), \tag{22}$$

where ρ_0 is the cut-off level that maximizes the pledgable income to the lender, derived by

[12] Indeed, because the maximum pledgeable income $P(\rho^1) \geq I - A$ is evaluated at $\eta = \eta_{min}$, and the pledgable 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 (16).

setting the first derivative of (19) to zero: $\rho^0 = E_G(\pi) - \eta_{min} E_G(\pi^D) < \tilde{\rho} < \rho^1$.

To summarize, the solution to the contract above, we obtain the following decision rule for innovating and the optimal level of cash holding depending on the initial assets of the firm:

- If $A < I - P(\rho_0, \eta_{min})$: low assets - do not innovate
- If $A \geq I - P(\rho_0, \eta_{min})$: sufficient assets - innovate. Moreover:
  - If $I - P(\rho_0, \eta_{min}) \leq A < I - P(\rho^1)$: intermediate assets - innovate and hold cash amount $\tilde{\rho}$;
  - If $A \geq I - P(\rho^1)$: high assets - innovate and hold cash amount ρ^1.

This solution establishes Result 1 in the text.

Table 1: 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: Globalization and Cash Holdings: China Shocks; OLS

	(1)	(2)	(3)	(4)
	No interaction	X=SIZE	X=NW	X=IC
expSHOCK	-0.143	-0.801***	-0.610***	0.0116
	(0.110)	(0.234)	(0.229)	(0.123)
impSHOCK	-0.0933	-0.0698	-0.123	-0.114
	(0.105)	(0.164)	(0.168)	(0.112)
expSHOCK_X2		0.355	0.265	0.205**
		(0.238)	(0.234)	(0.0953)
expSHOCK_X3		1.034***	0.676***	-0.469***
		(0.261)	(0.255)	(0.123)
impSHOCK_X2		-0.113	-0.0564	0.143**
		(0.140)	(0.142)	(0.0569)
impSHOCK_X3		0.0380	0.109	0.0838
		(0.169)	(0.173)	(0.0737)
r2	0.0923	0.0943	0.0960	0.124
N	41909	41909	41888	37116

Notes: This table presents results of panel OLS regressions examining the effect of export and import shocks *vis-à-vis* China on cash holding. All regressions include firm-, sector-year-, and country-year fixed effects as well as other firm-level controls such as total sales, operating cash flow, and a tercile dummy variable. Standard errors in parentheses are clustered at the firm level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 3: Globalization and Cash Holdings: China Shocks; 2SLS

	(1) No interaction	(2) X=SIZE	(3) X=NW	(4) X=IC
expSHOCK	0.0274	-4.116***	-3.996***	-4.670***
	(0.947)	(1.437)	(1.471)	(1.580)
impSHOCK	-0.321	0.0861	-0.0248	-0.810*
	(0.282)	(0.356)	(0.385)	(0.458)
expSHOCK_X2		2.786**	3.102***	5.275***
		(1.128)	(1.134)	(1.858)
expSHOCK_X3		6.180***	5.769***	7.435***
		(1.194)	(1.203)	(1.276)
impSHOCK_X2		-0.578*	-0.276	0.889
		(0.312)	(0.345)	(0.542)
impSHOCK_X3		-0.578*	-0.323	1.028***
		(0.347)	(0.375)	(0.373)
First stage estimates	*Dep. var*: expSHOCK			
$expSHOCK(IV)$	0.484***[13.22]			
$impSHOCK(IV)$	-0.0703*** [-4.52]			
F-stat.	124			
	Dep. var: impSHOCK			
$expSHOCK(IV)$	-0.194***[-4.2]			
$impSHOCK(IV)$	0.885*** [19.2]			
F-stat.	185			
N	41095	41095	41047	35491

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 regressions include firm-, sector-year-, and country-year fixed effects as well as other firm-level controls such as total sales, operating cash flow, and a tercile dummy variable. The bottom panel summarizes first stage estimation results. Standard errors in parentheses are clustered at the firm level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 4: Globalization and R&D: China Shocks; OLS

	(1) No interaction	(2) X=SIZE	(3) X=NW	(4) X=IC
expSHOCK	0.0592	-0.0801	-0.0551	-0.229**
	(0.0962)	(0.271)	(0.247)	(0.113)
impSHOCK	0.0581	-0.0935	0.0245	-0.0694
	(0.0826)	(0.121)	(0.125)	(0.0955)
expSHOCK_X2		0.189	0.130	0.316***
		(0.268)	(0.233)	(0.0788)
expSHOCK_X3		0.137	0.104	0.462***
		(0.278)	(0.253)	(0.102)
impSHOCK_X2		0.219**	0.0569	0.155***
		(0.111)	(0.110)	(0.0479)
impSHOCK_X3		0.118	0.00819	0.226***
		(0.129)	(0.128)	(0.0556)
r2	0.257	0.271	0.269	0.255
N	41909	41909	41888	37116

Notes: This table presents results of panel OLS regressions examining the effect of export and import shocks *vis-à-vis* China on $R\&D$. All regressions include firm-, sector-year-, and country-year fixed effects as well as other firm-level controls such as total sales, operating cash flow, and a tercile dummy variable. Standard errors in parentheses are clustered at the firm level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 5: Globalization and R&D: China Shocks; 2SLS

	(1) No interaction	(2) X=SIZE	(3) X=NW	(4) X=IC
expSHOCK	-0.713	-4.918***	-5.413***	-2.406*
	(0.854)	(1.342)	(1.437)	(1.282)
impSHOCK	-0.124	-0.516	-0.584	-0.615*
	(0.249)	(0.360)	(0.411)	(0.353)
expSHOCK_X2		3.349***	4.512***	1.677
		(1.106)	(1.224)	(1.369)
expSHOCK_X3		5.837***	6.302***	2.460**
		(1.088)	(1.183)	(0.983)
impSHOCK_X2		0.695**	0.698*	0.619
		(0.325)	(0.392)	(0.382)
impSHOCK_X3		0.507	0.839**	0.875***
		(0.340)	(0.387)	(0.269)
N	41095	41095	41047	35491

Notes: This table presents results of panel 2SLS regressions examining the effect of export and import shocks *vis-à-vis* China on $R\&D$. All regressions include firm-, sector-year-, and country-year fixed effects as well as other firm-level controls such as total sales, operating cash flow, and a tercile dummy variable. Standard errors in parentheses are clustered at the firm level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 6: Globalization and Cash Holdings: Tariff; OLS

	(1)	(2)	(3)	(4)
	No interaction	X=SIZE	X=NW	X=IC
expMFN	-0.437	2.324*	1.620*	0.528
	(0.449)	(1.354)	(0.892)	(0.823)
impMFN	-0.627	-0.354	-0.175	-1.161
	(0.864)	(1.209)	(1.209)	(0.997)
expMFN_X2		-2.788	-2.052**	-1.115
		(1.783)	(0.902)	(0.884)
expMFN_X3		-3.842**	-2.893***	-1.014
		(1.496)	(1.064)	(0.762)
impMFN_X2		-0.786	-0.790	1.301**
		(1.318)	(1.303)	(0.568)
impMFN_X3		0.00654	-0.362	0.646
		(1.329)	(1.309)	(0.719)
r2	0.106	0.109	0.109	0.140
N	29779	29779	29761	26450

Notes: This table presents results of panel OLS regressions examining the effect of export and import tariff changes on cash holding. All regressions include firm-, sector-year-, and country-year fixed effects as well as other firm-level controls such as total sales, operating cash flow, and a tercile dummy variable. Standard errors in parentheses are clustered at the firm level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 7: Globalization and R&D: Tariff; OLS

	(1) No interaction	(2) X=SIZE	(3) X=NW	(4) X=IC
expMFN	0.190	1.300**	1.628**	0.184
	(0.319)	(0.630)	(0.726)	(0.385)
impMFN	0.179	-0.121	-0.285	-0.467
	(0.472)	(0.873)	(0.961)	(0.591)
expMFN_X2		-0.535	-1.022	0.141
		(0.493)	(0.679)	(0.188)
expMFN_X3		-1.903***	-2.280***	-0.188
		(0.694)	(0.799)	(0.288)
impMFN_X2		0.282	0.208	0.728**
		(0.826)	(0.931)	(0.329)
impMFN_X3		0.422	0.892	0.880**
		(0.963)	(1.040)	(0.446)
r2	0.290	0.303	0.304	0.285
N	29779	29779	29761	26450

Notes: This table presents results of panel OLS regressions examining the effect of export and import tariff changes on $R\&D$. All regressions include firm-, sector-year-, and country-year fixed effects as well as other firm-level controls such as total sales, operating cash flow, and a tercile dummy variable. Standard errors in parentheses are clustered at the firm level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 8: Globalization and Cash Holdings: China Shocks; US excluded; 2SLS

	(1) X=SIZE	(2) X=NW	(3) X=IC
expSHOCK	-1.003	-1.000	-1.915
	(1.310)	(1.379)	(1.538)
expSHOCK_X2	1.526	1.663	4.099**
	(1.231)	(1.221)	(1.910)
expSHOCK_X3	2.727**	2.609*	4.170***
	(1.282)	(1.350)	(1.329)
impSHOCK	0.833	0.360	-0.564
	(0.934)	(1.103)	(0.643)
impSHOCK_X2	-0.857	-0.230	1.280**
	(0.755)	(0.945)	(0.580)
impSHOCK_X3	-1.017	-0.525	0.909**
	(0.784)	(0.956)	(0.438)
N	23899	23889	22294

Notes: This table presents results of panel 2SLS regressions examining the effect of export and import shocks *vis-à-vis* China on cash holding, excluding all US firms. All regressions include firm-, sector-year-, and country-year fixed effects as well as other firm-level controls such as total sales, operating cash flow, and a tercile dummy variable. Standard errors in parentheses are clustered at the firm level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 9: Globalization and R&D; US excluded; 2SLS

	(1) X=SIZE	(2) X=NW	(3) X=IC
expSHOCK	-2.520	-3.280*	-2.539
	(1.666)	(1.872)	(1.604)
expSHOCK_X2	0.641	2.313	2.653
	(1.490)	(1.698)	(1.859)
expSHOCK_X3	3.574**	3.955**	3.053**
	(1.635)	(1.897)	(1.428)
impSHOCK	-0.457	-0.718	-0.157
	(1.281)	(1.688)	(0.615)
impSHOCK_X2	0.870	0.974	0.337
	(0.973)	(1.390)	(0.445)
impSHOCK_X3	0.493	0.886	0.353
	(1.054)	(1.437)	(0.378)
N	23899	23889	22294

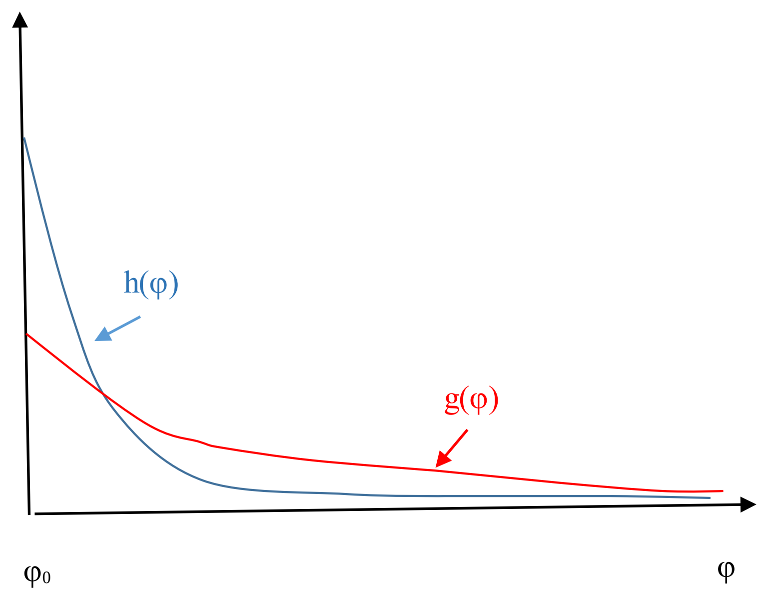
Notes: This table presents results of panel 2SLS regressions examining the effect of export and import shocks *vis-à-vis* China on $R\&D$, excluding all US firms. All regressions include firm-, sector-year-, and country-year fixed effects as well as other firm-level controls such as total sales, operating cash flow, and a tercile dummy variable. Standard errors in parentheses are clustered at the firm level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 10: Globalization and Cash Holdings: China Shocks; non-innovative firms; 2SLS

	(1) X=SIZE	(2) X=NW	(3) X=IC
expSHOCK	10.50	10.72	5.170
	(9.339)	(10.36)	(26.97)
expSHOCK_X2	1.880	5.549	-1.202
	(7.391)	(12.80)	(27.99)
expSHOCK_X3	6.206	5.518	18.58
	(7.407)	(7.127)	(18.20)
impSHOCK	0.303	-0.210	-2.661
	(1.718)	(1.986)	(3.224)
impSHOCK_X2	-0.0328	0.894	2.358
	(0.886)	(1.285)	(5.391)
impSHOCK_X3	0.374	1.440	2.912
	(1.126)	(1.232)	(3.884)
N	12941	12922	11593

Notes: This table presents results of panel 2SLS regressions examining the effect of export and import shocks *vis-à-vis* China on cash holding, restricting the sample to non-innovative firms only. All regressions include firm-, sector-year-, and country-year fixed effects as well as other firm-level controls such as total sales, operating cash flow, and a tercile dummy variable. Standard errors in parentheses are clustered at the firm level. (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Figure 1: 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: Timing of events in the 3-period model.

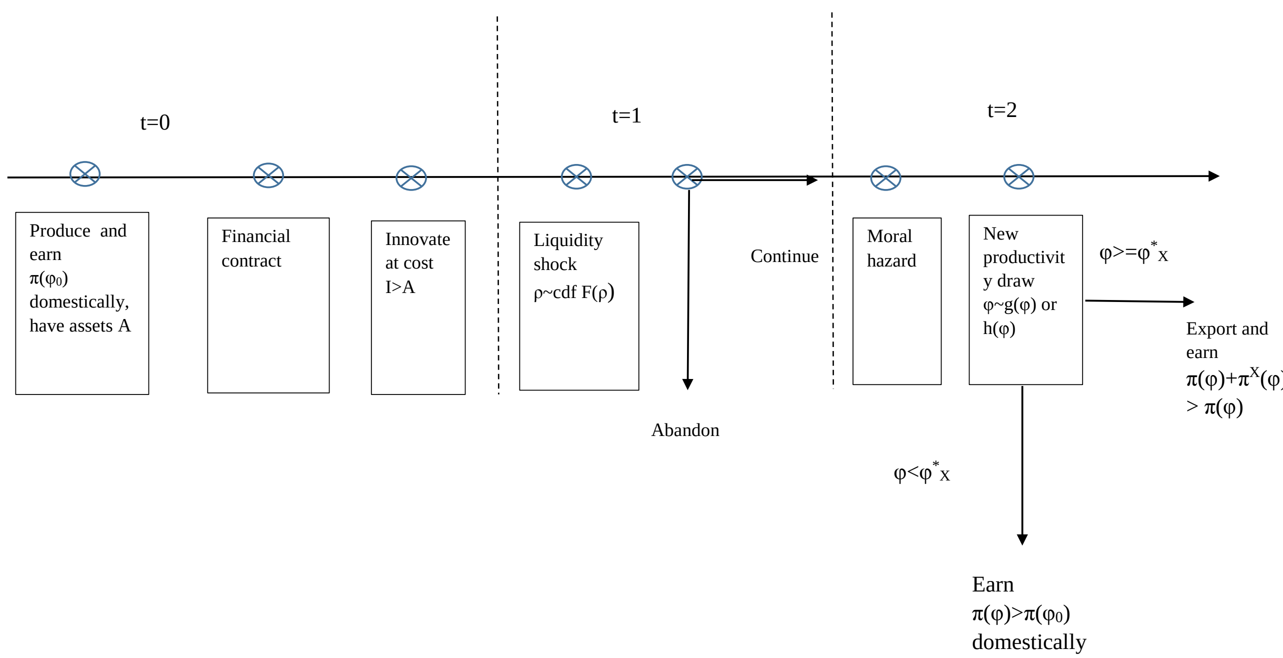
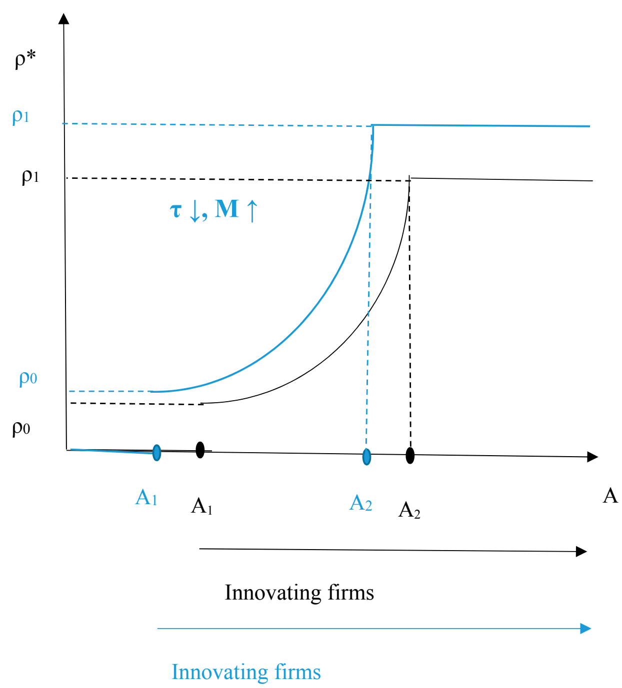
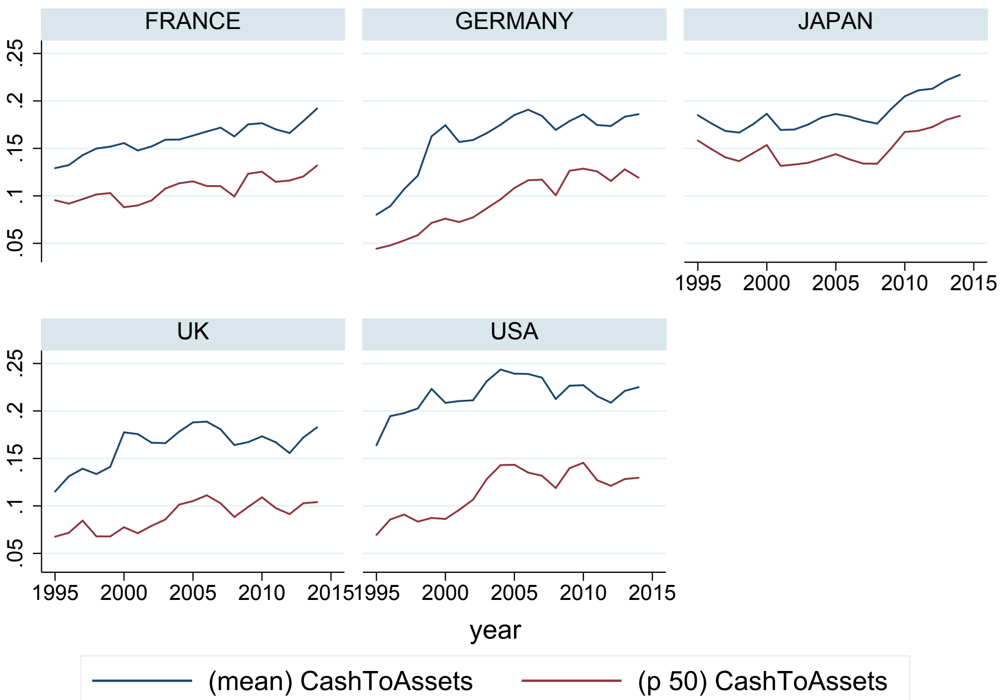


Figure 3: Set of innovating firms and schedule of cash holding as a function of balance sheet strength A.



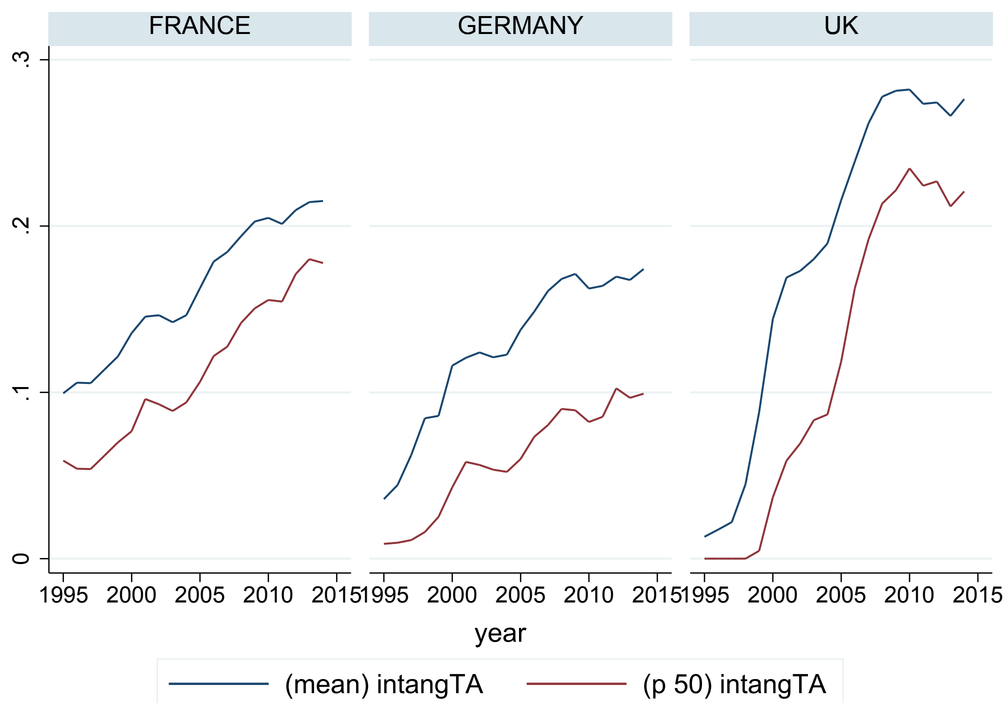
Note: Shift after trade liberalization is sketched in blue.

Figure 4: Cash and short-term investment in percent of total assets: mean and median.



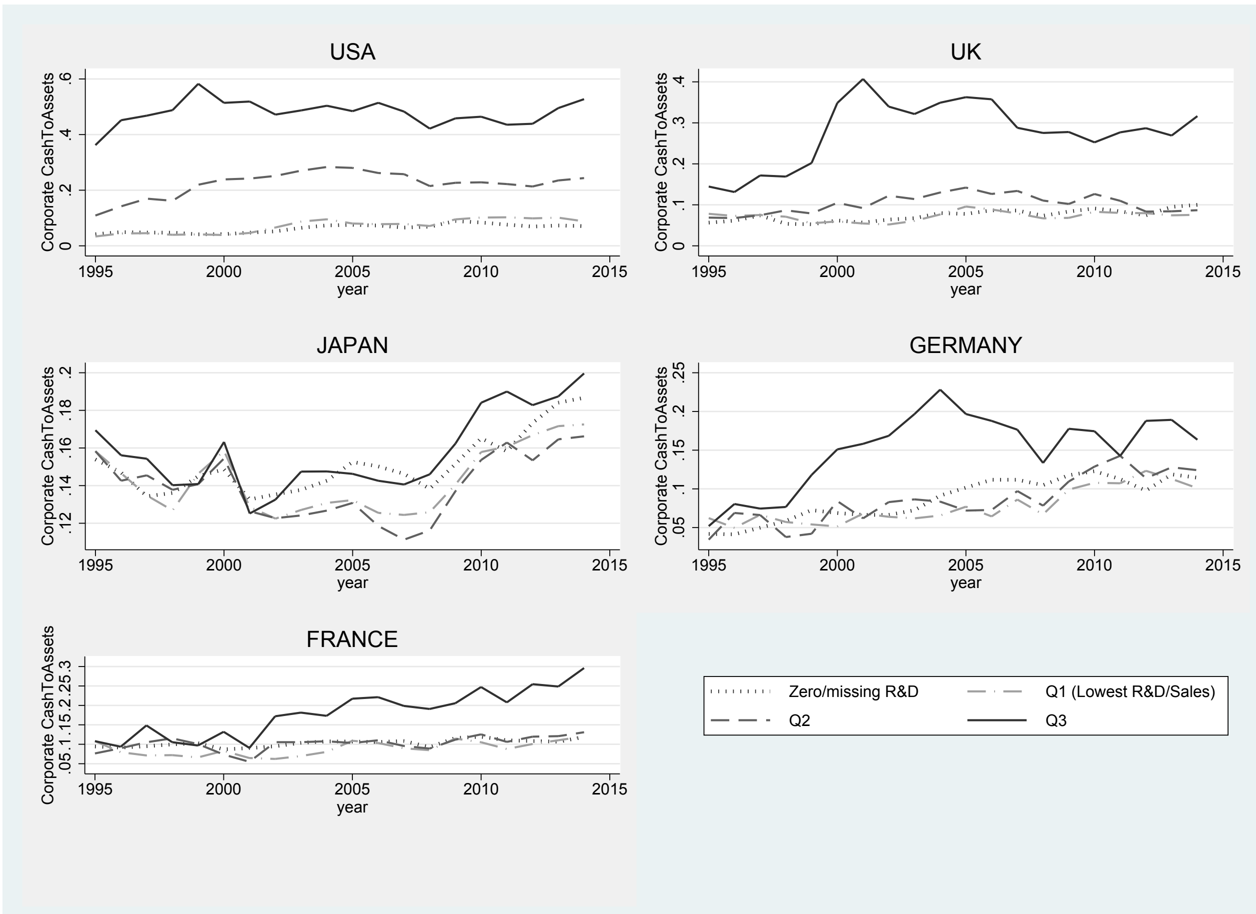
Source: Thomson Reuters Worldscope and authors' calculations. Cash to asset ratios are measured by the ratio of cash and short-term instruments to overall book assets. Mean and median cash ratios are calculated for each country year for firms with valid non-missing data.

Figure 5: Intangible capital as a share of total assets: mean and median.



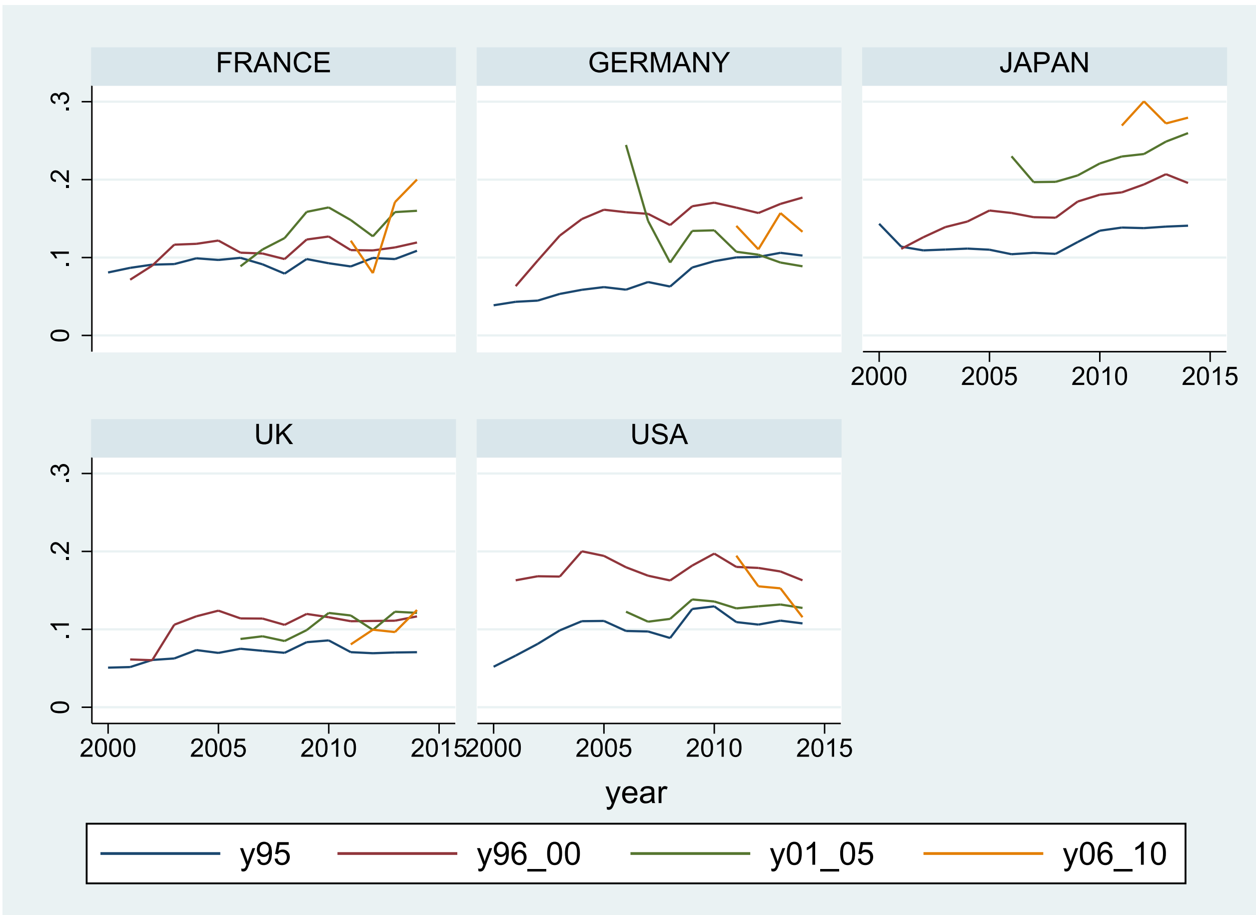
Source: Thomson Reuters Worldscope and authors' calculations. Mean and medians in each country year are calculated for firms with non-missing valid entries for intangible assets.

Figure 6: Cash holding evolution by innovation intensity.



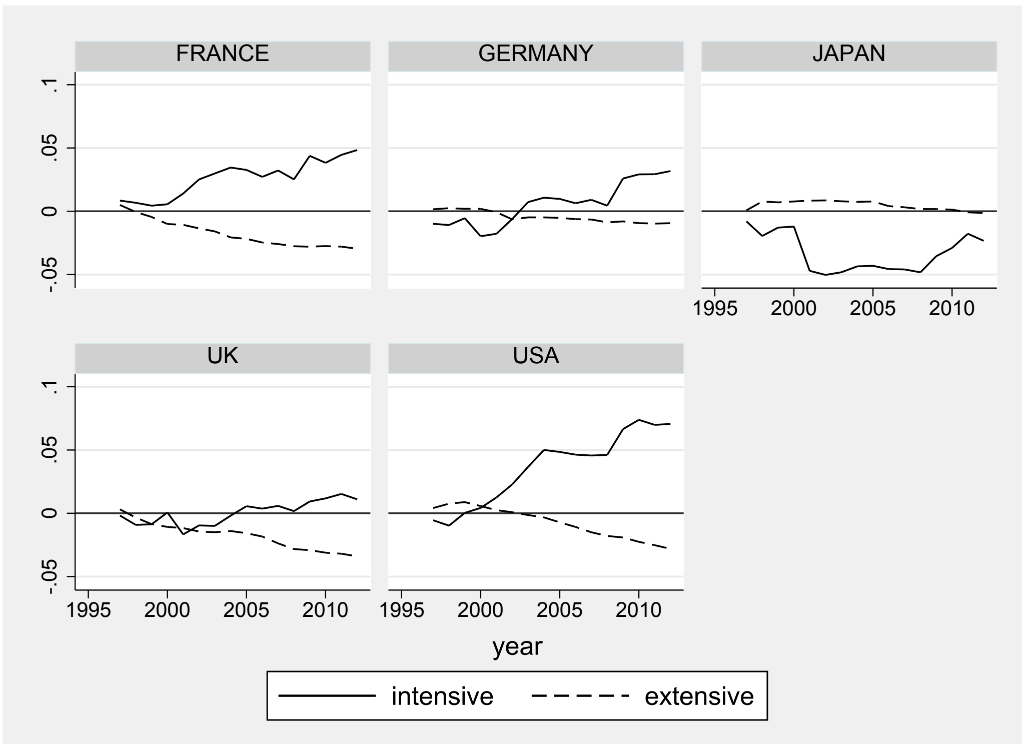
Source: Thomson Reuters Worldscope and authors' calculations. Cash to asset ratios are measured by the ratio of cash and short-term instruments to overall book assets, winsorized at the top and bottom 1 percent. Firms with positive $R\&D$ are sorted into terciles of innovation intensity (measured by 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 7: Cash holding evolution by entering cohorts.



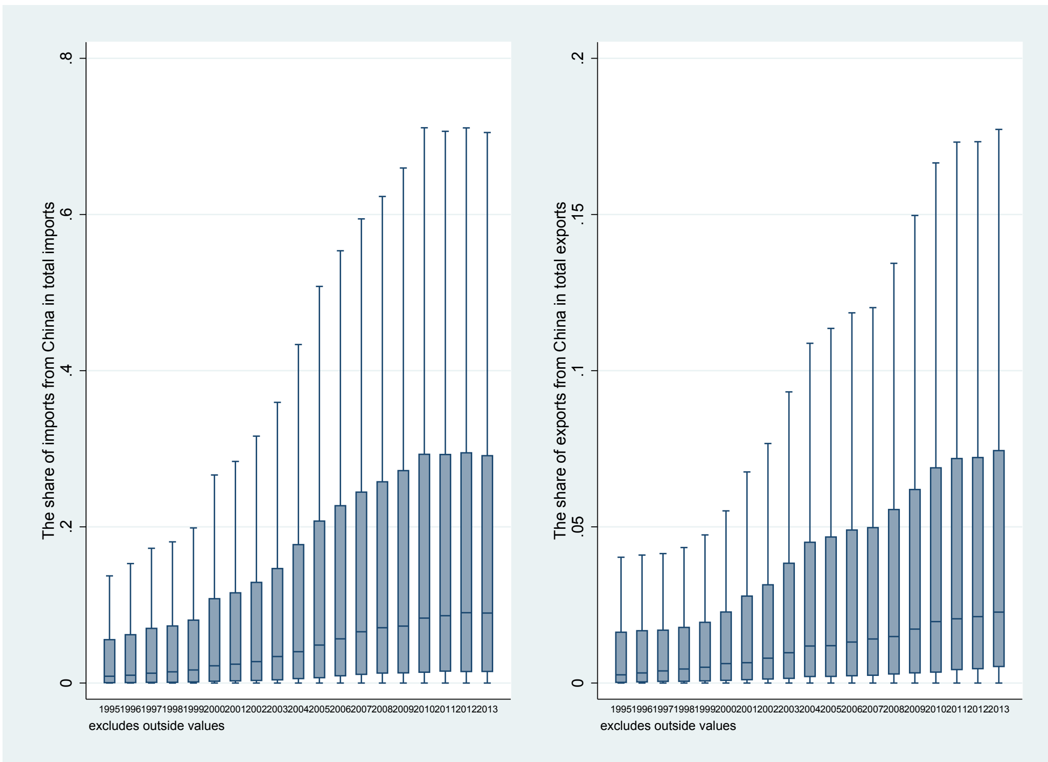
Source: Thomson Reuters Worldscope and authors' calculations. Cohorts are defined as set of firms that appear for the first time in the sample during each consecutive 5-year window. Lines show the median cash to asset ration within each cohort over time.

Figure 8: Decomposition of aggregate cash ratio to cumulative intensive and extensive margin contribution.



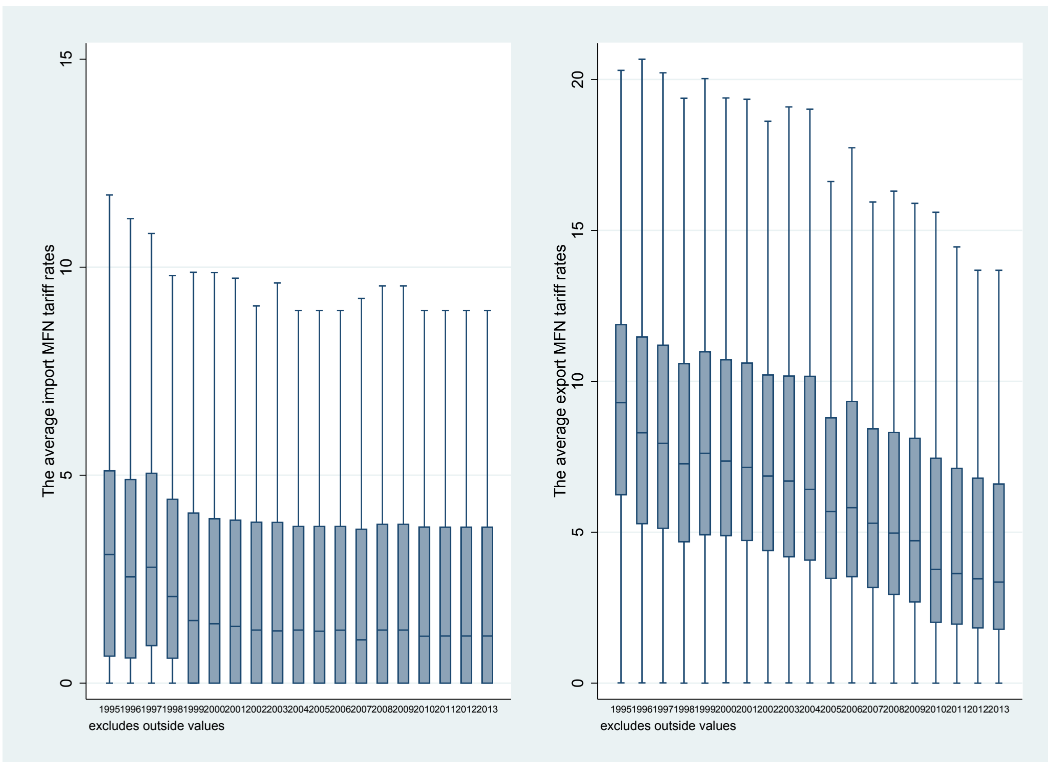
Source: Thomson Reuters Worldscope and authors' calculations. The decomposition of total change into intensive and extensive margin contributions follows equation (1) in the text. Cash to assets ratios are winsorized at the top and bottom 1 percent. Only firms with at least 2 consecutive observations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

Figure 9: The evolving role of China in global trade.



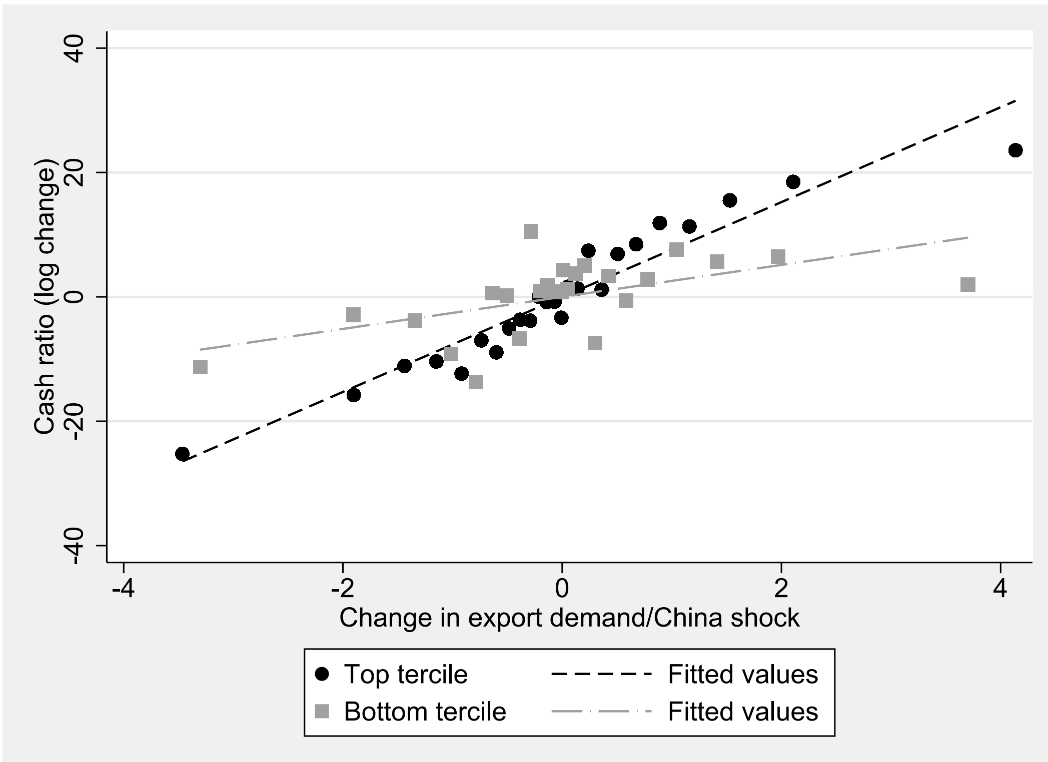
Source: UN Comtrade and authors' calculations; Country-SIC 2digit level distribution.

Figure 10: Global tariff liberalization.



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

Figure 11: Cash holding increases with higher export demand, more so for larger firms.



Notes: higher export demand is associated with higher cash holding, 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 holding, conditional on the firm fixed effect. The conditional correlation is plotted separately for firms in the top and bottom tercile of asset size distribution.