Determinants of Firm-Level Investment and Exporting

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Abstract

This paper proposes a theoretical model of finance constraints, investment, sales, and exporting, where finance constraints may influence not only export volume but also the export-to-sales ratio (export intensity) of a firm through heterogeneous investment decisions of firms, depending on their productivity. More productive firms can more easily bear the necessary costs of investment to finance export market access than smaller ones. The model suggests that financing constraints are reflected in or driven by three endogenous horsemen: collateral, internal funds (liquidity), and the costs of external finance. In order to investigate the theoretical predictions empirically the paper proposes a novel reduced-form method to analyze the impact of the three aforementioned horsemen for, according to the proposed theoretical model, two outcomes of interest: investment and export intensity. In order to avoid sources of possible endogeneity of the horsemen, the paper formulates a nonparametric approach for estimating the treatment effects of multiple continuous endogenous variables on outcome. The approach relies on reduced-form first-stage models which specify the continuous endogenous outcome as a function of observables and generate residuals which are used in a generalized control function to absorb endogeneity bias in flexible parametric or nonparametric models of continuous multivariate treatment effect functions. The empirical results for 99,456 French firms suggest that (i) firm-level investments rise nonlinearly with asset tangibility as well as the cash ratio, while they decline with higher interest rates as theory predicts, and (ii) the considered horsemen of financial constraints do not have a proportional effect on export intensity.

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1 Introduction

Much of the earlier work suggests that, while finance constraints affect the fixed costs to exporting – and, hence, the extensive margin of exports at the firm level – they do not affect variable (trade) costs of firm-level exporting. This suggests that, for exporters, credit constraints do not have an impact on the export-to-sales ratio, which is a testable hypothesis. This paper proposes a parsimonious theoretical model of finance constraints, investment, sales, and exporting, where finance constraints may influence not only export volume but also the export-to-sales ratio of a firm through heterogeneous investment decisions of firms, depending on their productivity. More productive firms can more easily bear the necessary costs of investment to finance export market access than smaller ones. This leads to a link between firm-level investment and productivity, unlike in most models of heterogeneous firms in the tradition of Melitz (2003). The positive correlation between productivity and investment inclination per se in conjunction with limited internal funds and restricted access to external finance suggests that small firms face tougher finance constraints than larger ones and, in turn, their exports are more sensitive to financing constraints than those of larger firms. The model suggests that financing constraints are reflected in or driven by three endogenous horsemen: collateral, internal funds (liquidity), and the costs of external finance. Empirical counterparts to those horsemen that are widely employed are firms’ possessions of tangible assets (for collateral), the cash ratios such as cash plus current assets relative to current liability (for liquidity), and interest expenses relative to liabilities (for costs of external finance).

No matter of how measured – through indirect measures reflecting finance constraints, through firm surveys, or through bank statements – measures of finance constraints as regressors likely involve problems of endogeneity in empirical analysis. The sources of this endogeneity are measurement error, self-selection of firms (into surveys, into certain kinds of behavior, etc.), framing effects in questionnaires, and simultaneity (e.g., taking credit to finance concurrent business activity). The paper proposes a novel reduced-form method to analyze the impact of three three aforementioned horsemen for, according to the proposed theoretical model, two outcomes of interest: investment and export intensity (export-to-sales ratio). In order to avoid sources of possible endogeneity of the horsemen, the paper formulates a non-parametric approach for estimating the (treatment) effects of multiple continuous
endogenous variables on outcome. The approach relies on reduced-form first-stage models which specify the continuous endogenous outcome as a function of observables and generate residuals which are used in a generalized control function to absorb endogeneity bias in flexible parametric or nonparametric models of continuous multivariate treatment effect functions. The paper graphically presents the results in a barycentric coordinate system with the three horsemen on the abscissae and firm-level investment or the export-to-sales-ratio on the ordinate.

The estimates are based on a data-set of 99,456 French firms for the years 1998-2007. For these firms and years, we observe five endogenous variables – investment and export intensity as outcomes and asset tangibility, cash ratio, and the costs of external finance as endogenous determinants thereof which we refer to as three horsemen behind financial constraints – and their fundamental drivers such as productivity, price-cost markups, domestic and foreign demand potential, and policy as well as natural trade costs that may not or only partly be determined by the firm. For the analysis of the impact of the three endogenous horsemen behind financial constraints on investment and export intensity, we employ a cross section of averages over the years 1998-2007.

Two results of the empirical analysis stand out. First, firm-level investments rise with asset tangibility as well as the cash ratio, while they decline with higher interest rates as theory predicts, but the relationship is not linear. Second, the horsemen do not have a proportional effect on export intensity. These findings are consistent with differential effects of financial constraints on export market entrants relative to incumbents: new exporters may face additional financing needs while at the same time their financing opportunities are lower relative to incumbent exporters.

The remainder of the paper is organized as follows. The next section reviews the closest-related existing research and puts the present paper in context. Section 3 and 4 outline the parsimonious model of a generic firm which draws productivity and decides upon investment and exporting in the presence of constrained external finance. Section 5 introduces the empirical framework. Section 6 provides sources and features of the data, while sections 7 and 8 summarize empirical findings regarding the determination of the endogenous horsemen and the compliance of the results with some of the assumptions, and it synthesizes the findings regarding the causal effects of financing constraints and their heterogeneity in the data. The last section concludes with a brief summary.
2 Literature review

This paper is related to earlier research in at least three aspects. First, it adds to the growing theoretical literature on international trade in the presence of financial constraints and financial frictions, respectively. Relative to that literature, the present paper motivates effects of such constraints and frictions not only on firm-level export volumes but also on export intensities. Second, it contributes to the literature on (trade-or-production-)cost-reducing investments of firms in open economies. In that regard, the paper illustrates that financial frictions and constraints affect investment along with export intensities simultaneously. Third, it relates to the empirical literature on the effects of financial friction variables on investment and exporting, utilizing a novel framework for causal analysis. An important contribution relative to earlier work is that the paper alludes to a joint nonlinear effect of three key horsemen of financial constraints on outcome (investment and export intensities) consistent with the proposed parsimonious but flexible theoretical model.

2.1 Related theoretical work

Earlier work on the impact of financial constraints and financial frictions to a large extent models such constraints and frictions as exogenous reduced-form parameters (Beck, 2003; Chaney, 2005; Manova, 2008, 2013). While such a strategy permits insights into the qualitative effects of related frictions and constraints, it disregards the fact that financial frictions and constraints themselves are unobservable and must be captured by proxy variables in empirical work and, even more importantly, that they emerge endogenously (Egger and Keuschnigg, 2013; Feenstra, Li, and Yu, 2013). For instance, Manova (2013) develops a partial equilibrium model where financial constraints are captured by an exogenous parameter which governs the fixed input requirement exporters need to incur relative to non-exporters. Qualitative effects of an increase of financial constraints are then gained from a comparative static analysis about the associated fixed-cost scaling parameter. By assumption of the baseline model, financial constraints may only affect the probability of exporting but not export volume of a given firm. Financial constraints may affect export volume and export intensity of a given exporter if financial constraints affect fixed and variable trade costs directly in a simultaneous way (this is analyzed in the online Appendix to Manova, 2013).

In contrast to Manova (2013), the present paper provides micro-foundations for the impact of financial constraints for fixed investment costs and variable trade costs. Firms invest in fixed costs in order to reduce their foreign market delivery costs. This suggests that investment and trade costs are both structurally affected by financial
constraints. Moreover, financial constraints are not modeled as an exogenous scaling parameter but linked theoretically to observable variables that represent the three (endogenous) horsemen which are determined by fundamental variables and whose (flexible) impact the empirical part of the paper focuses on. For instance, Egger and Keuschnigg (2012, 2013) and Feenstra, Li, and Yu (2013) model financial constraints as to arise endogenously from market imperfections associated with moral hazard and information asymmetries, whereby exports are affected indirectly.¹

Moreover, most of the earlier work on firm-level exports abstracts from considering a systematic link between fixed costs and variable costs of production and/or exporting. On a broader scale, the notion that trade costs are endogenous and, in fact, an output of economic activity is older than the trade-cost-centered new trade theory (see, e.g., Falvey, 1976). Moreover, industrial economists motivate fixed costs partly as to be incurred for the sake of lower production costs (see Petit and Sanna-Randaccio, 2000; Ngo, Raff, and Stähler, 2011).² More recently, trade economists increasingly view transport costs and market penetration costs to be endogenous to fixed investments costs of firms associated with tangibles or intangibles (see Arkolakis, 2010). For instance, Arkolakis (2010) introduces market penetration costs into a Melitz-type trade model of heterogeneous firms. Firms choose the marketing costs they want to incur and thereby determine the fraction of consumers they can reach in a certain market. Marketing costs feature decreasing returns to additional expenditures while the unit production costs are constant. Hence, incentives to firms to invest in market penetration costs affects the extensive consumer margin of demand per firm.

In contrast to Arkolakis (2010), in the present paper changing incentives to firms to invest in transport-cost-reducing technologies affects the financing structure of investments and the level of financial constraints within and across firms, and it affects the level and the intensity of exports within and across firms. Hence, while effects on exports emerge through changes in consumer prices in this paper, there are rationing effects beyond pricing by firms regarding the scope of consumers covered in Arkolakis (2010).³

²Most directly related to the present paper, Petit and Sanna-Randaccio (2000) combine the choice between a firm’s mode of foreign expansion with a production-cost reducing investment decision. Considering oligopolies they optimize their R&D investment after having chosen a mode of expansion. Ngo, Raff, and Stähler (2011) pursue a similar approach, though in the open economy and with heterogeneous firms.
³Notice that there is also a loose relationship between the endogenous trade cost argument addressed here and the literature about the endogenous market entry choice by exports versus trade-cost-jumping horizontal multinational firms (see Markusen, 1984; Horstmann and Markusen,
2.2 Related empirical work

The associated theoretical insights are then used to gauge the quantitative effects of financial constraints on the extensive and intensive firm-level margins of exports. Empirically, Manova (2013) finds that effects at the intensive margin of exports (the export sales of exporters) are bigger than those at the extensive margin (the probability of exporting of a given firm) are about one-half as small.

Further empirical studies investigating the effect of financial conditions on the economic development find substantial evidence for the negative impact of financial constraints using mostly exogenous variables reflecting these constraints (see Rajan and Zingales, 1998; Beck, 2002; Beck et al., 2005).

What the present study adds to the existing literature is that it does not consider the choice between different modes of serving a foreign market separately from the investment choice. As the export mode is considered as a continuous variable representing a range of integration from no exporting at the lower bound to FDI at the upper bound, the investment decision is taken such that profits are maximized and a specific state of integration on that continuous range is chosen. The insights following from our theoretical modeling are valuable as they deepen our understanding on the mechanisms of financial constraints. We find that the range of firms affected by financial constraints differs from that found by Manova (2013) as firm-level investment decisions vary with firm-specific characteristics. Furthermore, our model predicts that the endogenous investment decision has deeper impacts on aggregate variables such as price indices and consumer costs than would result from earlier models. Finally, the nonparametric empirical specification allows us to understand better the true impact of the three horsemen of investment as opposed to a linear approach.

3 The model

We propose a model which flows from a general framework of heterogeneous firms with monopolistic competition à la Melitz (2003). Consumers’ preferences are given by a CES consumption index

\[ U_j = \left( \sum_{i=1}^{J} \int_{\omega \in \Omega_j} q_{ij}(\omega) \frac{\omega}{\sigma} \, d\omega \right)^{\frac{\sigma}{\sigma - 1}}, \]

where \( \omega \) and \( \Omega_j \) denote an individual variety and the set of all varieties available to consumers in country \( j = 1, ..., J \), \( \sigma > 1 \) denotes elasticity of substitution, and \( q_{ij}(\omega) \) denotes the set-up cost relative to exporting in these models by fundamental factors – leading to an increase of foreign affiliate sales relative to such sales plus exports in a given country, aggregate or representative-firm (sales-weighted) export costs are reduced.
quantity consumed of variety \( \omega \) if it originates from country \( i = 1, ..., J \). By maximizing utility subject to the budget constraint \( R_j = \sum_{i=1}^{J} \int_{\Omega} q_{ij}(\omega) p_{ij}(\omega) d\omega \), where \( p_{ij}(\omega) \) is the consumer price of \( \omega \) from \( i \) in \( j \), consumption of \( \omega \) from \( i \) per representative household in \( j \) is \( q_{ij}(\omega) = \frac{R_j}{p_{ij}(\omega)^{-\sigma}} \) with \( P_j = \left( \sum_{i=1}^{J} \int_{\Omega} p_{ij}(\omega)^{1-\sigma} d\omega \right)^{1/1-\sigma} \).

Each variety is uniquely produced and supplied by a single firm so that there exists a continuum of firms. Having paid a sunk entry cost of \( w_{fei} \), firms draw their productivity level \( \varphi \) from a common distribution \( g(\varphi) \). These entry costs can be seen as a unique initial investment including the set-up of production facilities as well as R&D activities with the random draw \( \varphi \) being the uncertain outcome of this research effort. Accordingly, these sunk costs result in both tangible and intangible assets. Depending on the productivity level, \( \varphi \), and the prevailing variable costs per efficiency unit of the factor bundle, \( w_i \), firms face constant marginal costs of production of \( w_i \varphi \). For convenience, domestic production is assumed to be free of any fixed costs of production.

Unlike as assumed in Melitz (2003) or Manova (2008, 2013), exporting firms have to provide some infrastructure for serving a foreign market, whereby their variable costs of exporting depend on the firm-specific investment into this infrastructure. In particular, iceberg-type variable transport costs on exports of variety \( \omega \) from \( i \) to \( j \) are a decreasing and convex function of a firm’s investment into exporting, \( \tau_{ij}(I) > 1, \tau'_{ij}(I) < 0, \tau''_{ij}(I) > 0 \). The export investment function \( \tau_{ij}(I) \) is assumed to satisfy \( \left| \frac{\tau''_{ij}(I)}{\tau'_{ij}(I)} \right| > \sigma \left| \frac{\tau'_ij(I)}{\tau_{ij}(I)} \right|, \forall I > 0 \). This condition on the curvature of \( \tau_{ij}(I) \) ensures that infinite investment will not be an optimal solution while the functional form is kept quite flexible. Basically, this condition implies that the relative marginal effect of investment adjusted for the cost-sensitivity parameter \( \sigma \) is smaller than the relative marginal effect of investment on the slope parameter. We assume the cost of this investment to be \( F(I) = r_i I \). Figure 1 presents a sketch of such an export investment function. Investments can be financed both internally and externally, \( I = I^D + I^E \). Despite the financing costs are assumed to be equal for internal versus external funding as in a Modigliani-Miller setup, external financing is restricted by the value of tangible assets a firm can provide as collateral. Internal funds stem from domestic profits which can be generated without additional investment beyond the market entry costs, \( w_{fei} \), and are increasing in productivity. Collateral, in turn, is the tangible part of the set-up investment \( \lambda(\omega)w_{fei} \), \( 0 \leq \lambda(\omega) \leq 1 \) and, hence, external investment is restricted to be \( r_i I^E \leq \lambda(\omega)w_{fei} \).

Profit maximizing firms will decide upon their optimal export investment in a

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\(^4\)Notice that we assume that sunk costs in country \( i \) are identical across firms and involve a constant factor bundle \( f^e_i \) and unit-specific bundle costs \( w_i \) for any variety \( \omega \) produced in \( i \). The
first stage and choose their prices in a second stage. We can solve for these variables by backward induction. First, we derive the optimal price given $\tau_{ij}(I)$. Under monopolistic competition firms will charge a constant mark-up over marginal costs, $\frac{\sigma}{\sigma - 1}$, leading to standard domestic profits

$$\pi_{ii}(\omega) = \frac{R_i P_i^{\sigma-1}}{\sigma} \left( \frac{\sigma}{\sigma - 1} \frac{w_i}{\varphi} \right)^{1-\sigma}$$  \hspace{1cm} (1)$$

and an export profit function depending on the investment into exporting:

$$\pi_{ij}(I) = \frac{R_j P_j^{\sigma-1}}{\sigma} \left( \frac{\sigma}{\sigma - 1} \tau_{ij}(I) \frac{w_i}{\varphi} \right)^{1-\sigma} - r_i I. \hspace{1cm} (2)$$

In order to determine their optimal feasible investment level firms maximize their export profits subject to $I$, hence,

$$I^*(\varphi) = \min \left( \arg \max_I \{ \pi_{ij}(I, \varphi) \}, \frac{1}{r_i} \frac{R_i P_i^{\sigma-1}}{\sigma} \left( \frac{\sigma}{\sigma - 1} \frac{w_i}{\varphi} \right)^{1-\sigma} + \frac{\lambda(\omega) w_i f_i^e}{r_i} \right). \hspace{1cm} (3)$$

term $w_i$ can be seen as the price of cost-minimizing bundle of all inputs without loss of generality.\footnote{Clearly, in general equilibrium we would want $r_i$ to be proportional to $w_i$ to ensure existence of a solution. However, this restriction is not necessary in partial equilibrium which is sufficient for the present purpose, which focuses on effects to individual firms rather than on economies at large. In general, it seems plausible that sunk costs involve factors that are available to the firm prior to access to external finance whereby the composition of the factors behind $f_i^e$ would differ from the one behind $I$ so that $w_i$ would differ from $r_i$.}
Once we have solved for the optimal feasible investment level, \( I^*(\varphi) \), we can derive optimal export variables such as prices, revenues, and profits (noting that domestic results do not deviate from standard Melitz (2003) results) as

\[
\begin{align*}
\pi_{ij}(I) &= \frac{R_j P_j^{\sigma-1} \left( \frac{\tau_{ij}(I^*(\varphi)) w_i}{\varphi} \right)^{1-\sigma}}{\sigma} - r_i I^*. \\
p_{ij}(\varphi) &= \frac{\tau_{ij}(I^*(\varphi)) w_i}{\varphi} \sigma^{-1} \\
r_{ij}(\varphi) &= \frac{R_j P_j^{\sigma-1}}{\sigma} \left( \frac{\tau_{ij}(I^*(\varphi)) w_i}{\varphi} \sigma^{-1} \right)^{1-\sigma}
\end{align*}
\]

Given the relatively mild assumptions on the behavior of the export investment function, \( \tau_{ij}(I) \), we are able to obtain some comparably powerful results.

**Proposition 1.** Given the same amount of tangible assets and identical costs of financing, investment is (weakly) increasing in productivity.

*Proof.* See appendix.

Since \( \tau_{ij}(I^*(\varphi)) \) is decreasing in productivity, differences in prices, revenues, and profits are even more dispersed in this setup than in Melitz (2003). More productive firms charge even lower prices and earn even higher revenues and profits than in the benchmark model without financin constraints and export-cost-reducing investments. In particular, the export intensity, defined as exports over domestic revenues, is increasing in productivity while it is constant in a standard Melitz (2003) framework.

**Proposition 2.** Given the same amount of tangible assets and identical costs of financing, more productive firms have a higher export intensity than less productive firms, \( \zeta_{ij}(I^*(\varphi)) = \frac{R_j P_j^{\sigma-1} \left( \frac{\tau_{ij}(I^*(\varphi)) w_i}{\varphi} \right)^{1-\sigma}}{R_i P_i^{\sigma-1}}, \) where \( \frac{\partial \zeta_{ij}(I)}{\partial \tau_{ij}(I)} \frac{\partial \tau_{ij}(I)}{\partial \varphi} > 0 \).

*Proof.* In the text.

More productive firms may may afford transport-cost-reducing investments and thereby generate higher returns. They will do so up to the point where the next dollar of investment will yield a marginal profit which does not exceed the marginal investment costs. Economic integration of production in this model does not only directly depend on tariff policy but also on policies affecting firms’ incentives to invest in transport cost reductions.\(^6\) Since investment is unambiguously increasing

\(^6\)Relative to the literature on multinational firms (see Markusen, 2002; Helpman, Melitz, and Yeaple, 2004), where firms can influence market delivery costs by avoiding trade costs completely through foreign affiliate sales at fixed foreign plant set-up costs rather than exporting, firms may gradually affect trade costs through fixed investment costs in the present model.
in productivity, and the distribution of productivity establishes a unique ranking of profits, we can define a clear export productivity cutoff, $\varphi^*$, from the zero-profit condition

$$
\pi_{ij}(I^*(\varphi^*)) = \frac{R_j P_j^{\sigma-1} \left( \frac{\sigma}{\sigma - 1} \tau_{ij}(I^*(\varphi^*)) \frac{\omega}{\varphi^*} \right)^{1-\sigma}}{\phi - r_i I^*(\varphi^*)} = 0.
$$

Figure 2 plots graphically how firms are distributed across non-exporters, constrained exporters and unconstrained exporters according to their level of productivity. There may be a range of firms with very low productivity which do not export, since their realizable export profits at optimal trade-cost-reducing investment results are negative, $[0, \varphi^*)$. All firms in the interval $[\varphi^*, \infty)$ are exporters, however, there may be an intermediate productivity interval $[\varphi_c, \varphi_c] \in [\varphi^*, \infty)$ with constrained exporters which are not able to invest the optimal amount as their maximum attainable investment level lies below the optimal one.

Firms are financially constrained in this setup if their optimal investment level is not financially feasible. As exogenous factors might vary across firms, the severeness of financial constraints is heterogeneous across firms. In the model, this is reflected in the firm-specific tangibility parameter $\lambda(\omega)$ – reflecting a firm’s ability to offer collateral – and in the access to internal funds as reflected in firm-specific domestic profits, $\pi_{ii}(\omega)$. Notice that an increase in collateral or domestic profits will not affect
unconstrained firms in Figure 2, while an increase of these firm-specific fundamen-
tals behind financial constraints will affect investment, trade costs, and exports of
constrained firms. However, the range of constrained firms increases to the left as
well as to the right. This is different for financing costs as reflected in \( r_i \), since these
costs pertain to internal as well as external finance and will affect all firms.

**Proposition 3.** A given financially constrained firm’s investment will increase, if
the collateral it can provide (\( \lambda(\omega)w_i f_i^e \)) and/or its internal funds (\( \pi_{ii}(\omega) \)) rises. A
decline in financing costs (\( r_i \)) will increase the level of investment of all firms.

*Proof.* See appendix.

Figure 3 summarizes the results of Proposition 3.

4 An extension of the model: variable collateral requirements

In a setting as described above banks are modeled very risk-averse as all their lending
is backed by collateral of the firm. Suppose now banks take the market interest rate
as given but are willing to lend at lower collateral if the market interest rate is
higher. By this behavior banks can simply adjust the risk they take to the risk
premium contained in the interest rate. As before the collateral a firm can offer is
given by \( \lambda(\omega)w_i f_i^e \). However, the share of collateral a bank wants to be backed by
collateral is now \( n(\omega, r_i) \in (0, 1) \), \( \frac{\partial n(\omega, r_i)}{\partial r_i} < 0 \). This setting might lead to a situation
where some constrained firms can invest more as soon as interest rates rise. The
investment level of a constrained firms is given by:

\[
I^C = \frac{1}{\sigma} \left( \frac{\sigma}{\sigma - 1} \right)^{1-\sigma} \left( w_i \right)^{1-\sigma} + \lambda(\omega)w_i f_i^e \frac{n(\omega, r_i)}{n(\omega, r_i)r_i},
\]

where now the term \( n(\omega, r_i) \) enters. As interest rates rise two counteracting effects
occur: On the one hand rising interest rates reduce the investment level as less
investment can be made given an amount of internal and external funds. On the
other hand, with an increase in interest rates banks are willing to lend more and the
amount of external finance provided rises:

\[
\frac{\partial I^C}{\partial r_i} = -\frac{1}{(r_i)^2} \frac{R_i P_i^{\sigma-1}}{\sigma} \left( \frac{\sigma}{\sigma - 1} \right)^{1-\sigma} \frac{\lambda(\omega)w_i f_i^e}{n(\omega, r_i)(r_i)^2} - \frac{\lambda(\omega)w_i f_i^e n'(\omega, r_i)}{(n(\omega, r_i)r_i)^2},
\]

where the last term enters positively and might overcompensate the negative effect
from the first two terms. As before, firms that are not constrained are affected
(a) A decrease in internal funds/decrease in collateral

(b) An increase in financing costs

Figure 3: Counterfactual analysis of export-cutoffs and range of constrained firms
negatively by rises in interest rates as their cost of investment rises. Figure 4 summarizes the results: Under variable collateral requirements it might be the case that as interest rates rise some firms are less constrained than before (or even not at all) since banks are willing to lend at lower collateral. However, at some point this effect is overcompensated by the negative effects of higher interest rates: For constrained firms this happens if the decrease in investment level that can be obtained by internal and external funds is higher than the additional external funds obtained. For unconstrained firms an increase in interest rates always lowers the level of investment as their cost of financing increase.

This model brings about interesting facts that can be tested empirically. First of all, investment levels are heterogeneous across firms and increase in productivity. Second, investment depends positively on the collateral a firm can offer in terms of tangible assets. Third, the availability of internal funds increases the overall investment opportunities of a firms. Fourth, investment decreases as the cost of external financing increase. Interestingly, these relations are non-montonic since more productive firms might be non-constrained. In this case, the marginal impact of internal funding and collateral on the level of investment are decreasing. The empirical section aims at testing these predictions empirically using a generalized propensity score method for multiple continuous treatment variables (Egger, von Ehrlich (2013)).
5 Empirical strategy

In order to estimate the average treatment effect of the three financial variables identified in the theory we make use of the generalized propensity score for multiple, continuous treatments in order to overcome potential endogeneity of the financial variables on the outcome variable investment. For a random sample of $i = 1, \ldots, N$ cross-sectional units we have a set of outcomes $Y_i(F_i)$, where $F_i = (F_{Ti}, F_{Ci}, F_{Ri})$ denotes the $1 \times 3$ vector of actual treatment levels of the financial variables Tangibility, Cashratio and Rate of interest. The investment ratio $Y_i(F_i)$ is a flexible function of these financial variables. Additionally, we define $F_m \in [f_m, f_m], m \in (T, C, R)$ as the set of potential treatment levels where $f_m \in \mathbf{F}_m$ denotes a particular level of potential treatments. Analogous to $F_i$, we may define the vectors of potential financial treatments and treatment sets as $f = (f_T, f_C, f_R)$ and $\mathbf{F} = (\mathbf{F}_T, \mathbf{F}_C, \mathbf{F}_R)$. In this context, we refer to $Y_i(f)$ as the unit-level dose-response function and to $\mu(f) \equiv E[Y_i(f)]$ as the average dose-response function. Each $N \times 1$ vector of treatments $F_m$ can be represented by a reduced-form specification as a function of covariates $X$ and a parameter vector $\beta_m$:

$$F_m = X\beta_m + \epsilon_m = \tilde{F}_m + \epsilon_m$$

Under the weak unconfoundedness assumption the potential outcome $Y_i(f)$ is conditionally independent of treatment status $F_m$:

$$Y_i(f_T, f_C, f_R) \perp F_{Ti}, F_{Ci}, F_{Ri}|X_i$$

We may now define the actual $i$-specific generalized propensity score (GPS) as the joint density of $F_i$ conditional on observed $X_i$ as $G_i = g(F_i, X_i)$, the potential $i$-specific GPS as the joint density of $f$ at $F_i$ given $X_i$ as $g(f, X_i) = g(f, F_i|X_i)$, and the unconditional joint density of $f$ which is averaged across all $F_i$ given $X_i$ in the sample as $g(f)$. Formally, these quantities are defined as

$$G_i = h(\tilde{F}_i), \quad g_i(f, X_i) = h(f - F_i), \quad g(f) = N^{-1}N \sum_{i=1}^{N} h(f, X_i), \quad (10)$$

where the general function $h(\cdot)$ is a multivariate log-concave density function which, for the whole distribution of $F_i$, is defined as

$$h(\tilde{F}) = \arg \max_{\ell \in \mathcal{F}} N^{-1}N \sum_{i=1}^{N} \ln \ell(\tilde{F}_i), \quad (11)$$

with $\ell(\cdot)$ being a specific log-concave functional form in the class $\mathcal{F}$ of all such forms. Once $h(\tilde{F})$ is estimated, we may evaluate it at any actual value $\tilde{F}_i$ and at
any potential value $f - F_i$. A key merit of the class of log-concave density functions (which include Beta, Gamma, Gaussian, Gumbel, logistic, Weibull and many other parametric density functions) is that they approximate many multivariate density functions very well.\footnote{Relative to nonparametric density functions, there is no need to estimate a bandwidth (see Rufibach, 2007, and Dümbgen and Rufibach, 2009), avoiding the associated curse of dimensionality associated with multivariate nonparametric density estimation (see Cule, Gramacy, and Samworth (2010)).}

In Appendix A.3, we outline a more conservative, Gaussian form of the GPS and discuss the associated results there in comparison to the ones based on the more flexible form in the main text.

After estimating the empirical counterpart of the GPS, $\hat{G}_i$, we model the unit-level dose-response function as a quadratic approximation of its arguments and estimate its parameters by OLS.

$$E[Y_i|F_i, G_i] = \alpha_0 + \alpha_1 F_{Ti} + \alpha_2 F_{Ci} + \alpha_3 F_{Ri} + \alpha_4 \hat{G}_i + \alpha_5 F_{Ti} \cdot \hat{G}_i + \alpha_6 F_{Ci} \cdot \hat{G}_i + \alpha_7 F_{Ri} \cdot \hat{G}_i + \ldots + \alpha_{7n-6} F_{Ti} + \alpha_{7n-5} F_{Ci} + \alpha_{7n-4} F_{Ri} + \alpha_{7n-3} (\hat{G}_i)^n + \alpha_{7n-2} (F_{Ti} \cdot \hat{G}_i)^n + \alpha_{7n-1} (F_{Ci} \cdot \hat{G}_i)^n + \alpha_{7n} (F_{Ri} \cdot \hat{G}_i)^n,$$  \hspace{1cm} (12)

where $\hat{G}_i$ denotes a consistent estimate of $G_i$. Let us generally use hats with estimated variables and parameters. Then, replacing in (12) the true parameters with estimates, all observable treatment levels, $F_i$, with potential ones, $f$, and all actual GPS values, $\hat{G}_i$, with potential ones, $\hat{g}(f, X_i)$, we obtain an estimate of the unit-specific dose-response function, $E[\hat{y}_i|f, X_i, \hat{g}(f, X_i)]$. Then, the average $f$-specific dose-response function is defined as

$$E[\hat{y}(f)] = \frac{1}{N} \sum_{i=1}^{N} E[\hat{y}_i|f, X_i, \hat{g}(f, X_i)].$$  \hspace{1cm} (13)

6 Specification and data on outcomes, financial constraints treatments, and observable fundamentals

The main source of data employed in the empirical analysis of this paper is balance sheet information from a panel of French firms as published by Bureau van Dijk in its Amadeus Database. The advantage of using data for France is that a large number of enterprises are covered, and that, unlike for most other economies covered by Amadeus, information about exports is available beyond balance sheet data.
Between 1998 and 2007, the database provides information on 994,560 observations, representing 99,456 firms. While in principal this represents a section of larger firms existing in France, statistical (e.g., regarding the productivity distribution) and behavioral parameters (e.g., relationships between individual characteristics of firms) are well represented in the subset of French firms covered in Amadeus (see Egger, Egger, and Kreickemeier, 2013, and the discussion of Toubal of this paper at the conference on ”Globalization and Labor Market Outcomes: Recent Advance” hosted by Banque de France in 2013). Beyond the mentioned firm-level data, we utilize sector-level information from national accounts as provided by INSEE and country-pair information on geographical variables as provided by the Centre d’Études Prospectives et d’Informations Internationales. A detailed discussion of the rationale behind an inclusion of the variables and their sources will be given in what follows. While we employ panel data for the estimation of some variables (in particular, productivity), the main part of the empirical analysis relies on a large cross section of firms which is based on averages of variables over the years 1998-2007.

6.1 Outcomes, $Y_i$

The theoretical model in Section 3 suggests that there are two firm-level outcome variables which financial constraints affect crucially in the present context: investments and export intensity. For both outcomes which vary at the firm level, the sources is the Amadeus database. Investments are defined as the average ratio of fixed assets in any year $t$ between 1998 and 2007 and the previous year $t - 1$ for the average year in the sample period. Export intensity is measured as the average ratio of exports and total sales of a firm in the average year of the sample period.

6.2 Three horsemen of financial constraints , $F_i$

The model in Section 3 suggests that a firm’s exposure to financial constraints surfaces through three horsemen: the degree to which firms can pledge collateral to external investors (we will measure this aspect by asset tangibility); the liquidity of firms (we will measure this aspect by the cash ratio); and the costs of external finance as reflected by the interest charged by external investors per dollar of investment.

The asset tangibility measured as tangible relative to intangible plus tangible assets which largely reflect the relative importance of the tangible part in fixed assets. This is a widely-used measure for the degree to which firms may offer collateral and thereby reduce the risk to outside investors (e.g., banks or venture capitalists; see Manova (2013)).
The cash ratio is defined as cash over current liabilities which is a standard measure of liquidity in accounting and finance (see Hail (2002)).

The costs of external finance are defined as interest payments over total liabilities. This measure reflects the relative costs across firms – given a specific liability structure which we will control for – of external finance. For instance, the average risk of default per sector, the quality of an investment project, the longevity of the financial relationship between external investors and a given firm, induced by agency costs and asymmetric information all matter for the costs per dollar of external finance and are reflected in this measure (see Almeida and Campello (2010)).

Obviously, these three horsemen reflect financial constraints and, as such constraints themselves, are not exogenous to a firm. However, the theoretical model in Section 3 and research in accounting and finance provide guidance with regard to the fundamentals co-determining these horsemen.

6.3 Fundamentals, $X_i$

From the model’s point of view 21 types of variables exert an impact on the vulnerability of firms to financial constraints.

One key driver of all endogenous variables in most models of heterogeneous firms and trade is the (total factor) productivity across firms. The latter is not observed, but we estimate it in line with Levinsohn and Petrin (2003), using the following output and production factors for firms in the manufacturing sector: profit-adjusted value added net of profit or loss for firm $i$ in year $t$, $v_{it}$; labor input measured by the number of employees in firm $i$ at year $t$, $l_{it}$; capital inputs measured as total assets of firm $i$ in year $t$, $k_{it}$; an intermediate inputs as a proxy variable for technological change, $m_{it}$. We deflate the variables except for $l_{it}$ using price indices from French annual national accounts for 40 NACE Rev. 2 divisions as provided by INSEE.

Then, we include a measure of demand shocks – given certain characteristics of a firm – which reflects the standard deviation of sales across the years a firm is covered in the panel.

Moreover, we include measures related to the profitability of firms. Among those, there is the mark-up ratio calculated as operating revenues over operating profits in the average year a firm is covered in the data. of demand and demand shocks – given certain characteristics of a firm – which reflect log sales and the standard deviation of sales. The former is computed as the average of log sales per firm in the sample period, and the latter is the standard deviation of the level of sales across the years a firm is covered in the panel. Also, we include the material cost ratio to total sales of a firm in the average year. Recent research indicates
that firms whose sales depend more strongly on other firms’ inputs are more prone to supply shocks from outside the firm than others. Then, we include the profit tax ratio, capturing total profit tax payments over total before-tax profits. The latter measures to which extent profits generated may be captured by the firm for potential future investments. For a similar reason, we include the depreciation rate, measured by the ratio of depreciations to the fixed assets of a firm in the average year. The latter determines the net effect of two: to which extent tax payments may be reduced due to depreciations, and to which extent the capital stock needs to be renewed. The latter two effects measure the extent and of and the need for, respectively, new investments into fixed assets of the firm. Also, we include labor costs per employee as a measure of the extent to which firm sales are shared between firm owners and workers (see Egger, Egger, and Kreickemeier, 2013). All of the mentioned variables affecting firm-level profitability are available from Bureau van Dijk’s Amadeus database.

Then, we include a number of characteristics which inform us about the history of a firm. For instance, whether a firm is stock-market-listed or not, whether it is incorporated as a limited liability company or an unlimited liability company. These three forms of firms involve different accounting, reporting, and monitoring standards. Finally, we include a firm’s years since incorporation as a measure of firm age as an explanatory variable.

The variable natural trade costs reflects the average predicted effective ad-valorem trade costs from a gravity type model with a product-specific constant and partner fixed 5-digit product sector-level. Product-specific parameters are obtained from gravity equations that are estimated on log product-specific bilateral exports (from the United Nations’ Comtrade Database) among more than 200 countries covered in Comtrade as a dependent variable on log distance and an adjacency indicator from the Centre d’Études Prospectives et d’Informations Internationales’ Geographical Database as well as exporter-product and importer-product fixed effects for the average year in 1997-2009. The product-specific coefficients on the natural (geographical) trade cost variables are used as weights for the respective trade cost variables, and the weighted trade costs are then matched by concordance tables from United Nations Statistics Division onto 4-digit NACE Revision 2 codes as available in Amadeus for each firm. Clearly, in view of the model, these natural trade costs are relevant only to an extent that they can not be manipulated by a firm through its investments in transport technology.

Finally, we include a number of characteristics which reflect the ramifications of the financial situation of a firm which is independent of its endogenous horsemen. The log total assets measure a firm’s endowment with assets which determines its ability to provide collateral. The financial dependence of firms in the same
sector and year as firm \(i\) in the average year of the sample period. Moreover, we include a firm’s **subsidies ratio** – which measures a firm’s sales per subsidy the firm received – as a measure of access to subsidies which ceteris paribus reduces the need for external finance. E.g., some firms are located in regions, operate in sectors, or fall for other reasons into programs which the European Commission operates to foster cohesion, improve infrastructure, and support education and technological progress within the European Union. Also, we include the **leverage ratio** in the same sector firm \(i\) belongs in (in France in the average year covered) to measure the typical need for external finance of a firm as a given one. The **log cash flow**, the **log sales**, and the **cash-flow-sales-ratio** in the same sector as a given firm in France are three measures reflecting the access to internal finance for a typical firm of the same kind as a given one.

7 Estimating the GPS and assess its balancing power

First, we obtain the conditional mean of the treatment variables by regressing each financial variable on the set of covariates.

\[
F_m = X \beta_m + \epsilon_m
\]

Parameter estimates from this regressions are presented in table 1. In a next step we take the residuals obtained from this regression, which are now conditioned on the covariates \(\tilde{F}_m = F_m - X(X'X)^{-1}X'F_m\), and estimate the GPS from a multivariate log-concave density function

\[
\hat{G}_i = \hat{h}(\tilde{F}_i).
\]

Just as its binary counterpart the generalized propensity score has strong balancing properties. It follows from the definition of the GPS that

\[
X_i \perp 1\{F_{mi} = f_m\} | g(f, X_i).
\]

We can test this feature by allocating the covariates into groups assigned to different intervals of the financial variables. We divide each treatment variable at its median and combine these intervals to in total 8 groups. Comparing the means of the covariates in these groups shows a very substantial imbalance as shown in table 2 where the t-statistics for equality of means are shown. Especially variables related to the size of firms such as the log(sales) or log(L.Totalassets) as well as the age seem highly imbalanced. In total, only 66.67% of the means obtain t-statistics of
Table 1: Estimation results from OLS

<table>
<thead>
<tr>
<th>Variable</th>
<th>Tangibility</th>
<th>Cashratio</th>
<th>Interest Rate</th>
</tr>
</thead>
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<td>-0.188979***</td>
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<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
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<td>lsales</td>
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<td>-0.255651***</td>
<td>-0.001206***</td>
</tr>
<tr>
<td></td>
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<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>lcf</td>
<td>0.053285***</td>
<td>0.225996***</td>
<td>-0.000406***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>productivity</td>
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<td>-0.013894***</td>
<td>0.001643***</td>
</tr>
<tr>
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<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>cfratio</td>
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<td>0.001953***</td>
<td>-0.000006</td>
</tr>
<tr>
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<td>(0.00)</td>
<td>(0.00)</td>
</tr>
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<td>externaldep3</td>
<td>-0.000339***</td>
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</tr>
<tr>
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<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
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<td>taxratio</td>
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<td>-0.000065*</td>
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<tr>
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<td>(0.00)</td>
<td>(0.00)</td>
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<td>revprofitratio</td>
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<td>0.000038**</td>
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<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>subsidiesratio</td>
<td>-0.601916***</td>
<td>-0.992085**</td>
<td>0.081936***</td>
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<td>(0.10)</td>
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<td>(0.02)</td>
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<td>-0.009589***</td>
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<td>(0.00)</td>
<td>(0.00)</td>
</tr>
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<td>0.000126***</td>
<td>-0.000009***</td>
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<tr>
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<td>(0.00)</td>
<td>(0.00)</td>
</tr>
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<td>depreciationrate</td>
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<td>-0.000042</td>
<td>-0.000096*</td>
</tr>
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<td>(0.00)</td>
<td>(0.00)</td>
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<td>leverage3</td>
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<td>-0.000001</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>costratio</td>
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<td>0.000002</td>
<td>0.000000</td>
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<td></td>
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<td>(0.00)</td>
<td>(0.00)</td>
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<td>tradecost</td>
<td>0.013907***</td>
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<td>-0.000311</td>
</tr>
<tr>
<td></td>
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<td>(0.02)</td>
<td>(0.00)</td>
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<tr>
<td>listed</td>
<td>0.005668</td>
<td>0.021503</td>
<td>0.012215***</td>
</tr>
<tr>
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<td>(0.01)</td>
<td>(0.05)</td>
<td>(0.00)</td>
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<td>0.004577***</td>
<td>-0.0000517</td>
<td>-0.000052</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>ag</td>
<td>-0.013884***</td>
<td>0.024060***</td>
<td>0.001307***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>sigma</td>
<td>0.000001***</td>
<td>0.000001</td>
<td>0.000000***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>age</td>
<td>-0.000050</td>
<td>0.000267***</td>
<td>0.000011***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Ltotass</td>
<td>-0.000000*</td>
<td>-0.000000*</td>
<td>0.000000</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>cons</td>
<td>0.339009***</td>
<td>1.253822***</td>
<td>0.032295***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.02)</td>
<td>(0.00)</td>
</tr>
</tbody>
</table>

$R^2$ = 0.0838 0.1055 0.0125

mean equality lower than 2.576 indicating the 10% significance level. In order to obtain the GPS adjusted statistics we discretize the GPS in 15 blocks within each of the 8 groups. Then, we calculate the mean difference conditioning on each of
the block and compute the observations-weighted average for each group. Table 2 presents the t-statistics obtained by this method. We see that the t-statistics decreased significantly and the overall number of balanced means amounts to 92.8% confirming the balancing power of the GPS.

Table 2: Unadjusted and adjusted t-statistics across groups

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
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<td>sd-s</td>
<td>-2.170</td>
<td>-1.115</td>
<td>-2.573</td>
<td>-1.821</td>
<td>-1.007</td>
<td>-0.563</td>
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<td>3.829</td>
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<td>0.956</td>
<td>4.912</td>
<td>4.325</td>
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<td>1.114</td>
<td>0.634</td>
<td>0.640</td>
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<td>0.883</td>
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<td>-0.492</td>
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<td>-0.216</td>
<td>-0.353</td>
<td>-0.279</td>
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<td>-0.422</td>
<td>-0.357</td>
<td>-0.766</td>
<td>-0.904</td>
<td>0.074</td>
<td>0.773</td>
<td>-0.273</td>
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<tr>
<td>revprofitratio</td>
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<td>0.154</td>
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<td>0.029</td>
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<td>0.084</td>
<td>-0.341</td>
<td>-0.102</td>
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<td>0.141</td>
<td>0.654</td>
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<td>-0.119</td>
<td>-0.479</td>
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<td>depreciation</td>
<td>-0.568</td>
<td>-0.616</td>
<td>-1.221</td>
<td>-0.557</td>
<td>-1.244</td>
<td>-0.038</td>
<td>-0.482</td>
<td>-0.166</td>
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<tr>
<td>leverage3</td>
<td>-0.007</td>
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<td>-0.357</td>
<td>-0.766</td>
<td>-0.904</td>
<td>0.074</td>
<td>0.773</td>
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<tr>
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<td>-0.802</td>
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<td>0.261</td>
<td>0.074</td>
<td>0.301</td>
<td>0.185</td>
<td>-0.094</td>
<td>-0.120</td>
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<td>0.498</td>
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<td>-0.753</td>
<td>-0.464</td>
<td>-0.579</td>
<td>-0.233</td>
</tr>
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</table>
8 Estimating the dose-response functions for investment and the export intensity

In a next step we estimate the unit-level dose-response function by a polynomial approximation of degree 1 and 5 for investment growth and export intensity respectively where the choice of the polynomial is based on the Akaike information criterion. Table 3 summarizes the estimates of the unit-level dose-response which are now used to find the average dose-response function for potential treatment levels we are interested in. Dividing each treatment level into 10 incremental steps results in a grid of $10^3$ combination of potential treatment levels. In order to present the results graphically we chose a barycentric-illustration in figures 5 and 6: The circles on the lower panel indicate where on the barycentric triangle the $10^3$ potential treatment-combinations lie. Note that the circles do not indicate levels but ratios. Two points on the same line indicate the same ratio of those treatments the line is not originating from. For example, two points on the upper line starting in the interestrate vertex have both a tangibility-to-cash ratio ratio of 0.02/0.90. Black circles stand for outcomes which are significant at the 10% level obtained from 100 bootstrap replications. The upper panel indicates the level of the potential outcome as given by the dose-response function. For a given polygon this is the average outcome of all potential treatment combinations within that polygon. Figure 5 shows that investment is clearly increasing as we move to the vertex of cash ratio or tangibility while it is decreasing as it approaches the vertex of financing costs. On the other hand, the export intensity is more evenly distributed across treatment levels with a peak arising in the lower right corner.
<table>
<thead>
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<th>Variable</th>
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Figure 5: Barycentric illustration of the average dose-response with significance indicators at the 10 % level (black) (Growth in Investment)

Figure 6: Barycentric illustration of the average dose-response with significance indicators at the 10 % level (black) (Export Intensity)
9 Conclusion

This paper analyzes the role of financial constraints to firms on their investments and export intensity. It specifies a partial-equilibrium model of heterogeneous firms who choose their investment level for the sake of improving their efficiency of serving foreign consumers by reducing variable trade costs. The paper highlights a nonlinear relationship between randomly-drawn productivity and endogenous investment levels as well as exports at the level of the firm. This nonlinear relationship maps into a classification of firms as constrained non-exporters, constrained exporters, and unconstrained exporters. Provided a set of low-level assumptions the paper establishes a nonparametric relationship between productivity, financial market fundamentals, and other fundamental drivers of investment and exporting which is channeled through an endogenous degree of financial constraints, depending on the demand for and access to external finance.

The theoretical analysis highlights the fundamental role of three (endogenous) horsemen of financial constraints: asset tangibility, cash ratio, and the costs of external finance. Qualitatively, this analysis suggests that a bigger asset tangibility increases the pledgable collateral for external finance, which improves access to external finance. A higher cash ratio reflects higher liquidity and, hence, reduces the demand for external finance. Finally, higher costs per unit of external finance ceteris paribus also reduce the demand for external finance. In an extension, the paper illustrates that a higher cost of external finance does not necessarily reduce the demand for external finance, though. The three horsemen themselves and their impact on investment and exporting are determined by deep parameters the firms face: productivity, price-cost markups, domestic and foreign demand potential, and policy as well as natural trade costs that may not or only partly be influenced by the firm. The paper takes these insights to cross-sectional data on 99,456 French firms. For these firms, investment, export intensity, the three horsemen of financial constraints, and the fundamental drivers of these endogenous factors are observable or may be estimated. The derivation of the theoretical results and hypotheses based on low-level parametric assumptions motivate invoking such low-level assumptions also in the empirical part of the paper. Hence, the empirical analysis resorts to a flexible parametric model where the impact of three endogenous horsemen behind financial constraints is estimated on investments and export intensity at the level of the firm.

The paper employs a multivariate generalized propensity score approach for this analysis. In this framework, the three horsemen behind financial constraints are considered as continuous endogenous treatments. Using a control function approach in conjunction with a flexible polynomial representation, the impact of the horsemen
on investment and export intensity is the allowed to be as flexible as in the theoretical model.

The results suggest the following conclusions. First, firm-level investments rise with asset tangibility as well as the cash ratio, while they decline with higher interest rates as theory predicts. However, the horsemen do not have a proportional effect on export intensity. These findings point to an enriched theory where new exporters face additional financing needs while at the same time their financing opportunities are lower. High interest rates hence lower the entry of new firms and ceteris paribus increase the export intensity of incumbent exporters.
References


A Appendix

A.1 Proof of Proposition 1

Firms decide upon their investment level by maximizing their profit function with respect to $I$. Since there is a continuum of firms in a sector, the individual optimization does not take into account decisions by other firms:

$$\frac{\partial \pi_{ij}(I)}{\partial I} = (1 - \sigma)\frac{R_j P_j^{\sigma-1}}{\sigma} \left(\frac{\sigma}{\sigma - 1} c(\varphi)\right)^{1-\sigma} \tau_{ij}(I)^{-\sigma} \tau_{ij}t(I) - r_i = 0 \quad (14)$$

and the optimal investment of a firm is $I(\varphi) = \arg\max_I \{\pi_i(I, \varphi)\}$. It can be shown that $I(\varphi)$ is an increasing function: if there is an optimal investment $I^* > 0$ it is unambiguously increasing in $\varphi$. First, it is shown, that if there is a maximum investment it is a global maximum: Since $\tau_{ij}'(I) < 0$ and $\sigma > 1$, $\pi_{ij}$ is increasing in $I$. Furthermore, it is a concave function as:

$$\frac{\partial^2 \pi_{ij}(I)}{\partial I^2} = (1 - \sigma)B_j \left(\frac{w_i}{\varphi}\right)^{1-\sigma} \tau_{ij}(I)^{-\sigma} \left[\tau_{ij}''(I) - \sigma \left(\frac{\tau_{ij}'(I)}{\tau_{ij}(I)}\right)^2\right] < 0, \quad (15)$$

where $B_j = \frac{R_j P_j^{\sigma-1}}{\sigma} \left(\frac{\sigma}{\sigma - 1}\right)^{1-\sigma}$ is a positive constant. From $\left|\frac{\tau_{ij}''(I)}{\tau_{ij}'(I)}\right| > \sigma \left|\frac{\tau_{ij}'(I)}{\tau_{ij}(I)}\right| \forall I > 0$ it follows that $\tau_{ij}''(I) - \sigma \left(\frac{\tau_{ij}'(I)}{\tau_{ij}(I)}\right)^2 > 0 \forall I$. Since $(1 - \sigma) < 0$, this implies that $\frac{\partial^2 \pi_{ij}(I)}{\partial I^2} < 0$. If $\frac{\partial \pi_{ij}(I)}{\partial I} < 0 \forall I > 0$ then there exists no optimal investment and $I^* = 0$. Suppose a global maximum $I^*$ exists, then by $\frac{\partial^2 \pi_{ij}(I)}{\partial I^2} < 0$ being a monotonically decreasing function there exists at most one optimum which will be a maximum. By the implicit function theorem it can be shown that $I(\varphi)$ is increasing in productivity:

$$\frac{\partial I}{\partial \varphi} = - \left( \frac{\partial^2 \pi_{ij}(I)}{\partial I^2} \right)^{-1} \left( \frac{\partial^2 \pi_{ij}(I)}{\partial I \partial \varphi} \right)$$

$$= B_j^2 c_i^{1-\sigma} \tau_{ij}(I)^{-2\sigma} \left[\tau_{ij}''(I) - \sigma \left(\frac{\tau_{ij}'(I)}{\tau_{ij}(I)}\right)^2\right] (1 - \sigma)\tau_{ij}'(I) w_i^{1-\sigma} \varphi^{2-\sigma} > 0 \quad (16)$$

Suppose optimal investment lies above the maximum level of investment. Still, investment will be increasing in $\varphi$ as internal finds are increasing in $\varphi$. 

30
A.2 Proof of Proposition 3

A.2.1 Effect of decrease in cost of financing

Remember that optimal investment is given by

\[
I(\varphi) = \min \left( \arg\max_{I} \{ \pi_{ij}(I, \varphi) \}, \frac{1}{r_i} \frac{R_i P_i^{\sigma-1}}{\sigma} \left( \frac{\sigma - 1}{\varphi} \right)^{1-\sigma} + \frac{\lambda_i w_i f_i^e}{r_i} \right).
\] (17)

It can be shown that \( \arg\max_{I} \{ \pi_{ij}(I, \varphi) \} \) is decreasing in \( r_i \) by the implicit function theorem:

\[
\frac{\partial I}{\partial r_i} = - \left( \frac{\partial^2 \pi_{ij}(I)}{\partial I^2} \right)^{-1} \left( \frac{\partial^2 \pi_{ij}(I)}{\partial I \partial r_i} \right) = - (1 - \sigma) B_j c_i^{1-\sigma} \tau_{ij}(I)^{-\sigma} \left[ \tau_{ij} h(I) - \sigma \frac{\left( \tau_{ij} f(I) \right)^2}{\tau_{ij}(I)} \right] (1-1) < 0 \] (18)

Furthermore, \( \frac{1}{r_i} \frac{R_i P_i^{\sigma-1}}{\sigma} \left( \frac{\sigma - 1}{\varphi} \right)^{1-\sigma} + \frac{\lambda_i w_i f_i^e}{r_i} \) is clearly decreasing in \( r_i \). Consequently, a decrease in financing costs is increasing the level of investment for unconstrained as well as constrained firms.

A.2.2 Effect of decrease in collateral or internal funds

Unconstrained firms are not affected by changes in their collateral or internal funds. For constrained firms, the level of investment is given by \( I = \frac{1}{r_i} \frac{R_i P_i^{\sigma-1}}{\sigma} \left( \frac{\sigma - 1}{\varphi} \right)^{1-\sigma} + \frac{\lambda_i w_i f_i^e}{r_i} \). Both a decrease in collateral \( \lambda_i w_i f_i^e \) as well as a decrease in internal funds \( \frac{1}{r_i} \frac{R_i P_i^{\sigma-1}}{\sigma} \left( \frac{\sigma - 1}{\varphi} \right)^{1-\sigma} \) unambiguously lower the level of investment.

A.3 A Gaussian multivariate GPS function and associated results

Using a multivariate normal the \( N \times 1 \) GPS vector is given by:

\[
G_i = \frac{1}{(2\pi)^{3/2} |\Sigma|^{1/2}} \exp \left( -\frac{1}{2} (\widetilde{F}_i \Sigma^{-1} \widetilde{F}_i) \right),
\] (19)
\begin{equation}
G = \frac{1}{(2\pi)^{3/2}|\Sigma|^{1/2}} \text{exp} \left( -\frac{1}{2} \text{vecdiag}(\tilde{F}_i^{\prime} \Sigma^{-1} \tilde{F}_i) \right),
\end{equation}

(20)

where \( \tilde{F} = (\epsilon_m) \). First, we obtain the conditional mean of the treatment variables by regressing each financial variable on the set of covariates.

\[ F_m = X \beta_m + \epsilon_m \]

(21)

Parameter estimates from this regression are presented in table 4. In a next step we take the residuals obtained from this regression, which are now conditioned on the covariates \( \tilde{F}_m = F_m - X (X'X)^{-1} X' F_m \), and estimate the GPS from a multivariate normal distribution:

\begin{equation}
\hat{G} = \frac{1}{(2\pi)^{3/2}|\Sigma|^{1/2}} \text{exp} \left( -\frac{1}{2} \text{vecdiag}(\tilde{\hat{F}}_i^{\prime} \hat{\Sigma}^{-1} \tilde{\hat{F}}_i) \right),
\end{equation}

(22)

where \( \tilde{\hat{F}} = (\tilde{\hat{F}}_m) \). For the multivariate normal distribution to be adequate the residuals of the OLS in the first step should be distributed approximately normally. As figure 7 indicates the distribution of the residuals of tangibility is a slightly skewed while the distribution of residuals of interest rates seems a bit too narrow. However, a multivariate normal distribution seems still as a reasonable approximation.
Figure 7: Residuals of financial variables
### Table 4: Estimation results : Unit-Level Dose-Response

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Figure 8: Barycentric illustration of the average dose-response with significance indicators at the 10% level (black) (Growth in Investment)

Figure 9: Barycentric illustration of the average dose-response with significance indicators at the 10% level (black) (Export Intensity)