Who Finances Durable Goods and Why it Matters:

Captive Finance and the Coase Conjecture*

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First Draft: November 2013

This Draft: July 2015

Abstract

We propose an explanation for the prominent role of manufacturers in the financing of their own product sales, often referred to as "captive financing." By lending against their own product as collateral, durable goods manufacturers commit to support resale values in future periods, thereby raising prices and preserving rents today. Using data on captive financing by the manufacturers of heavy equipment, we find that captive backed models retain higher resale values. This, in turn, conveys higher pledgeability, even for individual machines financed by banks. Although motivated as a rent seeking device, captive financing generates positive spillovers by relaxing credit constraints.

1   Introduction

A substantial share of durable goods financed with credit in the US is not financed by banks, but rather by the manufacturer of the good itself. For firms making new investments in durable equipment used in agriculture, construction, logging, manufacturing, and printing, the share of debt financing extended by wholly-owned subsidiary lenders of the manufacturer was 58% as of 2013 and ranged from dominant (76% in agricultural equipment) to non-trivial (18% in printing) (see Figure 1). And while manufacturers are important lenders within these industries, they are also sizable enough to be important in aggregate. Manufacturing firms such as Toyota, John Deere, and Caterpillar originate loan portfolios in a given year which would rank them among the top banks in terms of business and non-credit card installment lending (as of 2012, #9, 15, and 17, respectively).[1] Recent work by Stroebel (2015) and Benmelech, Mesenzahl, and Ramcharan (2015), meanwhile, demonstrates the importance of these vertically integrated lenders in the markets for new housing and cars, respectively.

As the line between traditional banking and manufacturing firms' bank-like activities– so-called "captive finance"– is blurred, a natural question arises. What are the economic motives behind manufacturers financing their own sales? If banks are specialists in credit evaluation, monitoring, and fundraising and thus would be natural candidates to finance durable goods investment, what is the comparative advantage of captive finance?

Our paper provides a candidate answer to this question that focuses on the simple observation that when manufacturers are also lenders, they internalize the dynamic implications of their own production choices. Captive finance may thus serve as a solution to the famous Coase conjecture: even a monopolist producer of a durable good faces competition from its own future production, as customers may opt to delay their purchases if they expect prices to fall (Coase 1972). Based on this idea, Coase proposed that, without commitment to restrict production in each period, the monopolist firm would lose all its market power, producing the competitive quantity and charging the competitive price. We show that, by financing their own sales, manufacturers resolve this

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[1]This is based on bank holding company call report data, where bank loan portfolios excluded interbank, charge-card, or mortgage lending for comparability.
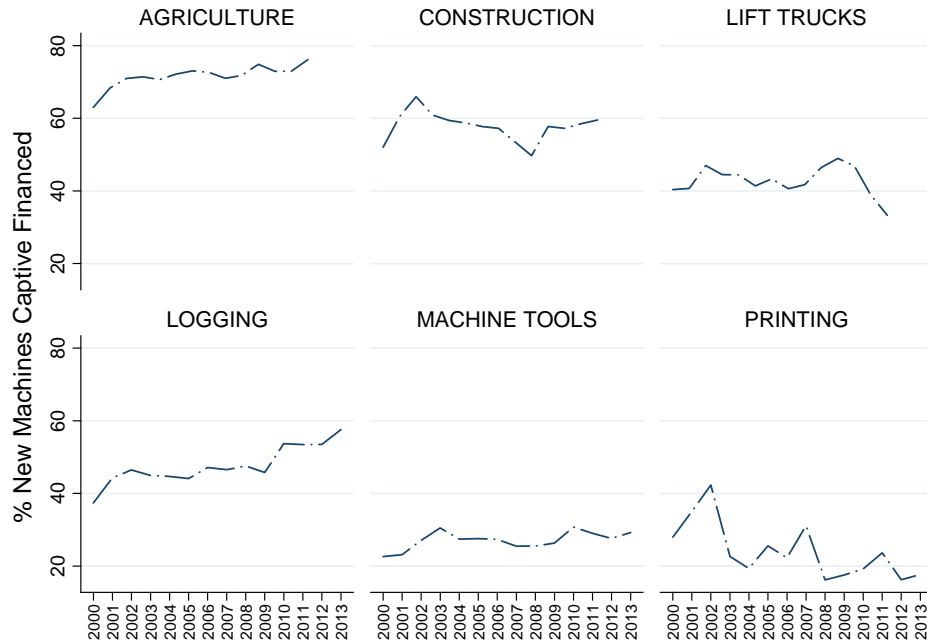
Figure 1: Captive Finance and Durable Investment The figure plots the percentage of new durable goods investment financed by captive finance subsidiaries of manufacturers in a variety of industries. Industry definitions were chosen by Equipment Data Associates, which provided these summary statistics.

time-inconsistency problem by making future profits dependent on resale values. By offering high enough loan-to-values to current customers, captive finance producers use the threat of strategic borrower default to commit to high resale prices in the future. While high resale values in Coase's model result from a manufacturer's commitment to restrict future production and thus avoid intertemporal competition with itself, we can imagine broader interpretations as well. Any actions that manufacturers can take that benefit former customers via higher secondary market prices– advertising, for example– present similar externalities. Absent a solution to the time-inconsistency problem, manufacturers will tend to underinvest in actions that support machines in which they no longer have a financial interest.

In addition to providing a new explanation for the ubiquity of captive financing for durable goods, our paper also highlights an important byproduct of captive finance.[2] Because captive

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[2]Brennan, Maksimovic, and Zechner (1988) develop a theory of vendor financing in which the financing is used as a means of price discrimination between rich and poor customers. Mian and Smith (1992) provide a unified analysis

financed products depreciate more slowly, active lending by the producer ensures greater asset pledgeability and lower down payments. Even non-captive lenders are able to offer lower down payments on models that receive significant captive finance support, effectively free-riding off of the producer's commitment.

We formalize our hypotheses by extending the durable goods model of Bulow (1982) to allow the manufacturer to provide debt financing. After sketching out a handful of key implications, we explore these implications using data on the financing and sales of new and used heavy machinery. Consistent with our predictions, we show that captive finance is predominantly used in oligopolistic markets where one or several firms control a large segment of the market, and therefore have a role in price setting. Moreover, large firms tend to be more active lenders for those products where they have more pricing power, suggesting more than just a "big firm" effect driving lending behavior.

Meanwhile, our central prediction that captive finance will predict higher resale values in secondary markets is readily apparent in the data. Using secondary market sales at used equipment auctions, we show that products which receive more captive support from their manufacturers depreciate more slowly. While part of this might be related to product durability, we still find higher resale values among predominantly captive financed models after conditioning out the effect of superior quality machines. Consistent with our hypothesis, the effect is limited to markets where producers have market power.

To help isolate the mechanism driving the observed correlation between captive finance and higher resale values, we exploit a natural experiment that shifted the share of captive financing for a specific set of equipment models. In 2007, Volvo, which had a large financing arm, acquired a division of Ingersoll Rand, which had a history of very little captive financing. We observe a sharp uptick in resale performance following the acquisition and corresponding increase in captive financing share by Volvo. In particular, even used machines produced by Ingersoll Rand prior to the division sale enjoy a slower depreciation path immediately following the sale, indicating that our results are not being driven by *ex ante* machine characteristics such as unobservable quality.[3]

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of a variety of alternative motivating factors behind captive finance, as well as early evidence on the subject. We return to these ideas later in the text.

[3]Stroebel (2015) also documents improved price performance of new homes financed by the builder, similar to our main result, but shows the effect is at least partially explained by variation in physical quality. We return to this

The theory and evidence support a role for captive finance as a rent seeking device for oligopolistic producers which would otherwise lack commitment to maintain higher prices/lower production over time. While healthy banks might arguably provide a public good, the initial analysis would suggest welfare losses from a healthy captive sector. But in the second part of our empirical section we explore a positive externality associated with a healthy captive finance sector. Products receiving strong captive finance support enjoy increased pledgeability due to their lower depreciation rates, and this is true even for individual machines which are financed by bank lenders. If credit constraints are a significant drag on profitable investment, captive finance provides a social good by relaxing these constraints, which may be particularly valuable in economic downturns. The focus on ex-post producer behavior as a driver of collateral pledgeability is new and complements recent empirical work emphasizing traditional determinants of pledgeability such as information asymmetry and redeployability (for example, Stroebel (2015) and Benmelech and Bergman (2009)).

Again using data on new and used equipment sales, we show that banks extend higher loan-to-values on equipment models receiving strong captive support from manufacturers. This becomes most valuable in periods of tight credit. In particular, there is a large shift towards models receiving captive support (and thus higher resale values) when lenders report tightening their conditions for collateral. This is evident even among purchasers using bank financing and therefore cannot be attributed to a pull back in bank credit. An evaluation of the welfare benefits of captive finance would therefore trade off the costs of enhancing the market power of large manufacturers within the product market against the benefits of reduced frictions in credit markets through enhanced pledgeability.

Before exploring these ideas in the data, however, we begin by formalizing the proposed role for captive finance and generating testable implications in the next section.

2   Hypothesis Development

In this section we discuss how a manufacturer of durable goods with market power can enhance its profits by offering financing for its products. We begin with the idea that durable goods monopolists

separate but complementary role for captive finance later.

face a time-inconsistency problem because they compete with their own anticipated future production (Coase 1972).[4] Because customers will pay higher prices for goods that are expected to better retain their value, the manufacturer today would like to commit to a future production path that would support high resale prices. However, such a commitment would not be credible since once the sale is made, the manufacturer would no longer have an interest in the value of the already-sold machines. Instead, the manufacturer tomorrow would choose production to maximize tomorrow's profits and in doing so would drive down the resale value of used products. Consequently, the price customers would be willing to pay today would reflect the anticipated lower value of their goods in the future.[5] Thus, the durable goods manufacturer's market power is undermined and his rents are eroded by intertemporal competition with himself. Coase (1972) introduced this problem and argued that with perfectly durable goods, a monopolist would revert to the perfectly competitive production path as the time between periods shrinks, and all of the rents from his market power would vanish.

Coase's work spawned a literature proposing solutions to this problem.[6] Probably the most applicable of these proposed solutions to our empirical setting (heavy construction equipment) is that the manufacturer lease rather than sell its output (Bulow 1982). By leasing, the manufacturer retains legal ownership of its products and thus internalizes the future resale value of equipment, providing the necessary incentives for him to commit to the optimal production path.

It is, however, not necessary for the manufacturer to retain ownership in order to align its incentives. The manufacturer can sell its output so long as it retains exposure to future prices on the down side. This exposure is precisely what is accomplished when the manufacturer provides secured debt financing for its customers. To see this, consider a manufacturer who finances the sale of equipment today. The terms of financing offered by the manufacturer will determine the

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[4]Though this literature refers to the time-inconsistency problem faced by a monopolist, actual monopoly is not necessary. It is enough that the manufacturer has some market power and faces a downward-sloping demand curve. While our empirical setting is not characterized by monopoly, it is plausible that the manufacturers we consider do have market power to varying degrees. We will exploit this variation in our empirical tests.

[5]An equivalent way to think about this problem is to note that, even in the absence of active resale markets, customers today have the option to delay their purchase and may choose to do so if the manufacturer cannot commit to keep prices high in the future.

[6]Bulow (1986) explores the possibility of the monopolist deliberately making his output less durable; Butz (1990) studies contractual provisions such as the use of most-favored-customer clauses; and Karp and Perloff (1996) and Kutsoati and Zabojnik (2001) focus on the deliberate adoption of an inferior production technology

future path of loan balances. Similarly, the production choices of the manufacturer will influence the future path of market prices of equipment. If at any point the manufacturer were to produce enough to push market prices below the outstanding loan balances, buyers would find it in their best interest to default on their loan and return the depreciated equipment to the manufacturer. With captive financing, the cost of depressing market prices would be borne by the manufacturer, making credible the manufacturer's commitment to keep future prices high. To the best of our knowledge we are the first to focus on this particular economic motivation for vendor financing, although Stroebel (2015) recognizes a potential role for integrated lenders in the housing market in solving this time-inconsistency problem in his footnote 26.

To formalize this argument, we extend the environment studied by Bulow (1982) to allow for secured debt financing from the manufacturer. Consider a two-period setting in which a durable goods producer faces a demand schedule for rental services of its output given by

$$p_r = a - bQ, \tag{1}$$

where Q denotes the total stock of machines in the economy and p_r is the one period rental price. The firm produces q_t machines in each period $t = 1, 2$ using a production technology with constant marginal cost which we normalize to 0. Machines do not physically depreciate between periods 1 and 2, except in the sense that they only have one period of usefulness remaining in period 2. We then have $Q_1 = q_1$ and $Q_2 = q_1 + q_2$. Finally, we normalize the discount rate to 0.

There is a frictionless resale market for used equipment. Since there are only two periods, the market price to purchase a machine in period 2 is equal to the rental price, $p_2 = a - bQ_2$. In contrast, a first-period buyer receives the equipment's services in both periods, the present value of which is given by $p_1 = a - bQ_1 + a - bQ_2 = a - bQ_1 + p_2$. This equation reflects the fact that the sales price of equipment in the first period is affected by the anticipated future value of equipment, which in turn is affected by second-period production. That is, buyers care about the resale value of their equipment so that the price they pay for equipment is the sum of the first-period rental

price and the resale value.[7]

As shown by Bulow (1982), a manufacturer that could commit to future production in this setting would choose a production production path characterized by:

$$q_1^* = \frac{a}{2b}, \quad p_1^* = a, \quad \pi^* = \frac{a^2}{2b}$$
$$q_2^* = 0, \quad p_2^* = \frac{a}{2}. \tag{2}$$

Here the manufacturer produces the amount that would be chosen by a monopolist producer of consumption goods in the first period. In the second period the manufacturer produces nothing, leaving the total stock of machines in the economy at the monopolist level. Total profits, given by π^*, are first-best.

A manufacturer that lacks an effective commitment mechanism, however, will not be able to capture π^*. Consider such a manufacturer that sells its output to buyers who finance through a bank (hence the b superscripts below). From the manufacturer's perspective, these sales are equivalent to cash sales, since there are no direct economic ties between the manufacturer and the banks who do the financing. In this case, as shown by Bulow, the manufacturer will choose a path given by:

$$q_1^b = \frac{2a}{5b}, \quad p_1^b = \frac{9a}{10}, \quad \pi^b = \frac{9a^2}{20b}$$
$$q_2^b = \frac{3a}{10b}, \quad p_2^b = \frac{3a}{10} \tag{3}$$

Two differences are immediately apparent when comparing this solution to the full-commitment solution. First, the manufacturer's profits are lower, illustrating the value that the firm can derive from any mechanism that enables it to commit to keep future prices high. This is because the firm's production in the second period drives down the market-clearing price in both the first and second periods. Second, because of second-period production, first-period machines have a higher depreciation rate. This has important implications for the financing contract that banks can offer, which we now consider.

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[7]Equivalently, we could think of the first-period sales demand as arising from the buyers' option to wait to purchase. Given an anticipated price path $\{p_1, p_2\}$, a buyer with productivity x will purchase in the first period if $2x - p_1 \geq x - p_2 \iff x \geq p_1 - p_2$. From the demand for rental services, the quantity of buyers with such productivity is $Q_1 = \frac{1}{b}(a - (p_1 - p_2))$. This is equivalent to the inverse sales demand above.

For now we assume that first period buyers finance their equipment through loans from a competitive banking sector. Competitive banking implies that $d_1^b + d_2^b = p_1^b$, where d_1^b denotes the down payment required by the bank and d_2^b denotes the size of the loan. We assume that buyers have limited commitment to repay and that a buyer who defaults cannot be excluded from the second-period market for machines. Under these assumptions, a buyer will default any time that he owes more than his machine is worth. It follows immediately that loan size is limited by $d_2^b \leq p_2^b = \frac{3a}{10}$.[8] The down payment must then satisfy $d_1^b \geq p_1^b - d_2^b = \frac{3a}{5}$. Indeed, under the assumption that funds are scarce for the buyer, these constraints would bind, and the unique optimal debt contract would be given by $d_1^b = \frac{3a}{5}, d_2^b = \frac{3a}{10}$. Intuitively, borrowers must put enough money down to cover depreciation in order to ensure repayment.

Now assume that the manufacturer provides financing for its first-period output. Can the manufacturer use the terms of financing to solve its time-inconsistency problem? Suppose that the manufacturer produces the first-best quantity in the first period: $q_1 = \frac{a}{2b}$. By lending an amount d_2 against these machines, the manufacturer effectively places a floor on their price in the second period.[9] If $p_2 < d_2$, buyers will find it optimal to default and the manufacturer will take back the depreciated machines, thus bearing the cost of having depressed prices. So, by setting $d_2^* = \frac{a}{2}$, the manufacturer can commit to keep second-period prices at the first-best level. This commitment, in turn, allows them to sell first-period machines at the first-best price $p_1 = a$, a price that reflects the high resale value these machines will have. Thus by choosing a debt contract of $d_2^* = \frac{a}{2}$ with a down payment of $d_1^* = \frac{a}{2}$, the manufacturer can achieve the full commitment profit level, π^*.

There are two important differences between the manufacturer's solution with bank financing and captive financing. First, since captive finance facilitates the first-best solution, machines depreciate more slowly when they are financed by the manufacturer. This is because the manufacturer can use financing as a mechanism to commit to high future prices. Second, the manufacturer is able to offer a higher loan-to-value when it finances its own machines. This is tied to the depreciation rate. Because the machines will be worth more in the future, the manufacturer can lend more

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[8] Rampini and Viswanathan (2010) formalize the equivalence between limited commitment of the type used here and collateral constraints.

[9] Technically, this is true for $d_2 \leq \frac{a}{2}$, but there would never be any reason for the manufacturer to make larger loans than this.

without pressing the buyers into default. In fact, since the threat of default is what provides commitment to the manufacturer, it is more accurate to say that the manufacturer *must* offer a higher loan-to-value. If it were to offer the same financing contract as we found under bank financing, it would lack the commitment to keep secondary market prices high.

While the stylized setting above conveys the important economic intuition driving our empirical tests, in our data captives and banks coexist as potential lenders. We analyze this setting in the appendix. With both captives and banks, depreciation rates are decreasing in the proportion of machines that are financed by the manufacturer. We find ample support for this prediction in the data. Another testable implication of the analysis is that the resale value to which the manufacturer commits raises pledgeability even for machines financed by banks. This pattern is also readily apparent in the data. Thus, while it may be motivated as a rent seeking device by manufacturers, a valuable byproduct of captive finance is its ability to relax credit constraints for buyers of products that receive captive support.

In motivating our hypotheses we have discussed the manufacturer's time-inconsistency problem in terms of production decisions. While this follows the previous literature, our empirical tests do not focus on production quantities. This is partially by choice and partially by necessity. First of all, manufacturers are very careful to obscure information about quantities sold, even going so far as manipulating serial numbers. Yet even with information on quantities, it would not be clear how to treat quantities of makes and models which may be close substitutes. More importantly, the central insight in Coase's original paper goes beyond quantity choice and applies generally to any actions taken by durable goods producers that impact future values enjoyed by past customers. Advertising, the introduction of new models, the quality and pricing of repair and maintenance services, and even decisions which impact perceived firm longevity and, thus, the expected availability of parts and service in the future will all determine the prices faced by past customers trading in their old models. (Hortacsu, Matvos, Syverson, and Venkataraman 2013) present evidence linking manufacturer financial distress to resale values. To the extent that firms do not fully internalize the effects of these choices on their past customers, captive finance will serve a role in providing commitment to high resale values.

3 Data

To test the hypotheses derived above, we focus our attention on the market for heavy equipment used in construction and agriculture. We focus on heavy equipment for a number of related reasons. First, to match the interesting features of the model, we need a less-than-perfectly competitive industry such that production and financing choices can interact meaningfully. While not monopolistic, the market for heavy machinery is controlled by a handful of large firms. By way of example, the most purchased piece of equipment in our sample is a skid-steer loader- a small, four-wheeled machine with lift-arms capable of pushing or lifting heavy material. In 2012, 5 manufacturers produced 93% of debt-financed skid-steers in the US. Thus, it seems plausible to presume that individual manufacturers have pricing power.

The durable quality of goods is also central to our argument. Returning again to skid-steers, the median used skid-steer financed with secured credit in 2012 was 8 years old. Durability, meanwhile, begets a healthy secondary market, which is both a feature of the model and allows us to track prices over time.

Finally, we focus on heavy equipment because of its nature as capital investment (as opposed to a consumption good). Although, in theory, our hypotheses apply to consumer durables equally well, we think that some of the more interesting implications of our theoretical findings pertain to the potential link between captive finance and pledgeability and how this may impact borrowers facing credit constraints. To the extent that the relaxation of credit constraints is an important outcome of captive financing, any resulting impact on firm investment could have large spillover effects for the aggregate economy.

For our primary tests, we rely on two distinct sources of data. One, produced and sold by Equipment Data Associates ("EDA"), tracks financing statements filed by secured lenders for sales – new or used – of heavy equipment financed by secured debt (hereafter, the "UCC data", because statements of financing are designated as the means of documenting liens under the uniform commercial code). We use these financing statements to infer the extent to which financing is done by manufacturers or by competing banks, our central predictions having to do with how much financing

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support a manufacturer lends to a given model.[10] We also use a limited sample of the data which allows us to observe the actual loan amount extended by the lender and an EDA-formulated estimate of the equipment value, thereby allowing us to infer loan-to-value, or percent down payment.

The data on financing statements are self-reported by lenders motivated by the need to "stake a claim" to specific pieces of collateral. In the event of a default on a secured loan in which multiple lenders report liens against the same piece of equipment, the first lender to have filed a UCC financing statement on that specific piece of equipment is given priority. Thus lenders have strong incentives to promptly report the collateral they have lent against. Financing statements are publicly available, but EDA sells cleaned and formatted versions going back to 1990. An introduction to financing statements and the claim-staking process is available in Edgerton (2012), which is the first and only other work we are aware of to use these data.

The second dataset we exploit is produced by EquipmentWatch, a data provider which reports results from heavy equipment auctions going back to 1993. While not comprehensive, we have data on the sales/purchases of over one million pieces of equipment from the largest auctioneers of heavy equipment. The machine-level observations include sales price, as well as both auction and equipment information such as age, condition, and make/model.

The machines in our data represent substantial purchases for the average buyer. The average estimate of equipment value from EDA and actual sales prices at auction are \$89,455 and \$30,750, respectively. The difference partially reflects the fact that, whereas auction sales include both cash and debt financed sales, the EDA estimates only reflect sales financed by secured debt. Additionally, auctions are composed almost exclusively of used sales, while financing statements include new and used sales. For reference, the appendix lists the most common machine types and manufacturers in the UCC data by observation count.

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[10]Although it is debatable as to whether or not financing statements are required for leases, the data and conversations with the data provider suggest that it is a common practice to file financing statements for both loans and financing leases. As a result, we include both leases and loans in our analysis. The focus of our analysis will be who finances the equipment, not the legal form of the contract, although leases admittedly provide potentially a more powerful device for aligning manufacturers incentives to support resale prices since they are the residual owner in a lease even without default. See Eisfeldt and Rampini (2009) for a theory of leasing based on borrower financial constraints.

4 Results

4.1 Captive Finance and Resale Support

Our central hypothesis, and thus the first testable implication we investigate, is that firms that provide their own financing to buyers are able to commit to higher future resale values. For now, we take the variation in the availability of captive finance support as given, although we'll show that, in practice, the incentives to extend captive financing are closely linked to market power.

Table 1 explores this link by comparing, on a model-by-model basis, estimated depreciation rates in the used equipment market with the degree of financing support offered for each model. Specifically, the variable *MODEL CAPTIVE SUPPORT* is the percentage of new machines of a given model financed by a captive finance lender over the entire sample. Note, we only observe purchases financed with secured debt, so our measure of captive support is conditional on debt financed purchases. Our focus on captive support only over new machines allows us to isolate the effect of captive financing availability, rather than variation in new vs. used sales, which is closely related to lender type. As a point of reference, the average make and model has *MODEL CAPTIVE SUPPORT* of 28%.

Meanwhile, we estimate depreciation rates using the auction sample, by regressing the log sales price on log machine age. Regressions are estimated on a model-by-model level. Before running model-level regressions, year fixed effects, estimated over the entire sample, are removed from both equipment age and price. Thus, time fixed effects are treated as constant across model-specific regressions. Formally, our measure of depreciation comes from the regression

$$ln(\widetilde{AuctionPrice}_{i,t}) = \alpha_{model} + \delta_{model}ln(1 + \widetilde{EquipmentAge}_{i,t}) + \epsilon_{i,t} \tag{4}$$

where δ_{model} is estimated separately for each model based on the sales of individual machines, i, at auctions in year t, and $ln(\widetilde{AuctionPrice}_{i,t})$ and $ln(1 + \widetilde{EquipmentAge}_{i,t})$ are demeaned by the average yearly log price and log (1+) machine age at auction. Age is calculated as the number of years between the original manufacture date and the date of resale for each machine being sold.

δ_{model} captures the model-specific depreciation rate. It should be interpreted as the percentage loss in value for a proportional increase in age.

With a measure of depreciation in hand, we can now project it on the level of captive financing support available for a given model, *MODEL CAPTIVE SUPPORT*, again, estimated as the percentage of new model sales reported in the UCC data that were financed by a captive. To reduce noise, we limit ourselves to models for which we have 30 or more transactions in both the auction sales and the UCC data. After dropping equipment models with too few observations, we are left with 1,727 models with which to estimate the conditional mean depreciation rate based on captive support. To isolate the effect of financing, we control for fine level equipment-type fixed effects, as well as a set of 26 size dummy variables, where size is characterized by EDA based on important machine characteristics, often horsepower or weight.

Column 1 of Table 1 reports the estimates from the model

$$-\delta_{model} = \alpha + \beta_1 ModelCaptiveSupport + \beta_{2...k}Controls_{model} + \epsilon \tag{5}$$

We estimate a coefficient on *MODEL CAPTIVE SUPPORT* of -0.14, suggesting that moving from a fully bank financed model to one which is completely financed by the manufacturer would predict a reduction in the machine's depreciation rate by 14 percentage points. Meanwhile, the mean depreciation rate is 60%. (That is, doubling the median equipment age of 8 years to 16 years is expected to wipe 60% off of machine value). Figure 2 shows this graphically, plotting mean depreciation rates across levels of captive finance. While the relationship is flat for small amounts of captive financing, we can see that above some threshold amount (roughly 50% of machines), depreciation rates appear strongly inversely related to captive support.

A sensible response to the observed correlation between captive financing and machine characteristics is to look for alternative machine characteristics that might drive both who finances machines and how the machine holds its value. Note, the inclusion of machine-type and size fixed effects appears to rule out omitted variables related to physical features of machines or intended uses, say of backhoes vs. excavators. Instead, it seems more likely that plausible confounding
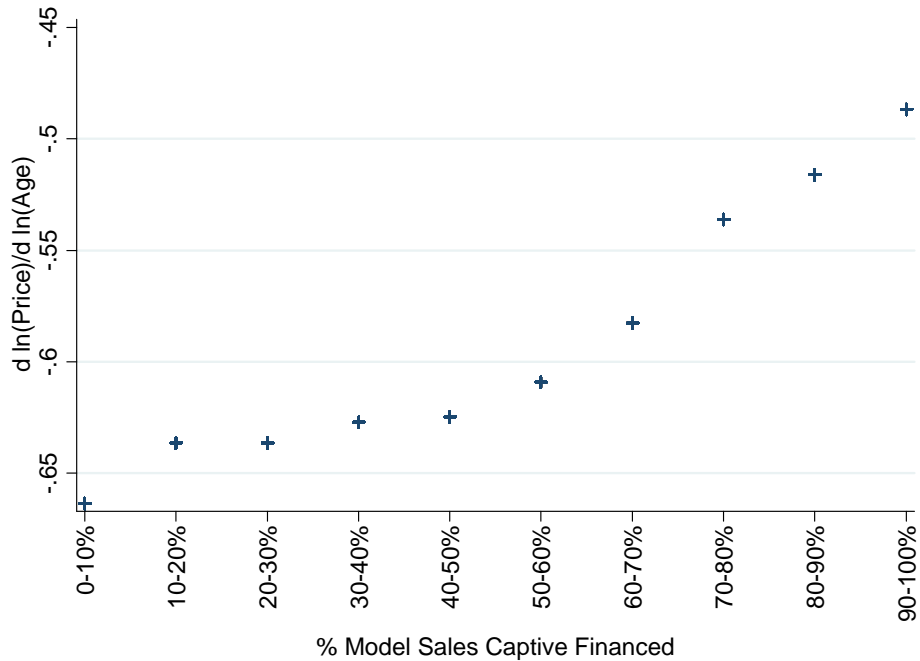
Figure 2: Resale Depreciation and Captive Finance. The figure plots mean depreciation rates across different levels of captive finance. On the horizontal axis is the percentage of new sales of a given model that are financed by the manufacturer. On the vertical axis is the proportional decrease in resale price for a proportional increase in age.

variables are in fact driven by manufacturer characteristics. One such argument might be that bigger, better companies make better machines and are capable of financing their own products. To address this, column 2 of Table 1 includes manufacturer fixed effects, testing for differentials in rates of product depreciation across models within a manufacturer. The coefficient on *MODEL CAPTIVE SUPPORT* is largely unchanged and not statistically distinct from the results in column 1 without manufacturer fixed effects. That is, unobserved manufacturer characteristics related to the level of captive financing do not explain the observed correlation.[11]

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[11]An alternative version of our main test is presented in the appendix in which we treat a given model-year (as opposed to model) as the unit of observation. For example, we can compare the price path of a 2000 John Deere 310G loader backhoe with a 2001 John Deere 310G loader backhoe. We estimate depreciation rates in a similar fashion as before. We then project that depreciation rate on a backwards looking measure of captive support for the model, taken from prior years' captive financing share for the same model. This has the benefit of allowing captive support to vary over time and allows us to include time fixed effects in the model to remove time trends from the variation in captive financing.

Using this alternative approach, we find similar results, albeit with attenuated coefficients. The attenuation is not necessarily surprising, given that the time varying measure of captive financing support is considerably noisier (and has a larger standard deviation) than the model-level estimate from Table 1. Even then, the coefficients fall within

The use of fixed effects and the persistence of the observed relationship between captive financing and resale values within manufacturer raises an interesting question. Why would a manufacturer provide financing to some makes and models but not others? The mechanism underlying our hypothesis suggests one potential answer. Manufacturers do not need captive finance and the commitment it provides in markets where they have limited ability to influence prices. Simply put, our hypothesis can only explain the use of captive finance by firms with market power.

It turns out this is consistent with the data. Figure 3 plots the use of captive finance across different models against the market concentration for the equipment type. The x-axis represents deciles of annually calculated Herfindahl index values for a given model's type of machine (e.g. skid-steer loader, mini-excavator, etc.), while the y-axis presents the average model-year captive support within each decile. An active role for captive finance appears to manifest more prevalently in concentrated industries where individual firms possess market power.

Table 2 brings us to a similar, but more pronounced, conclusion. Column 1 regresses *MODEL CAPTIVE SUPPORT* on the natural log of a model's market share, along with controls for equipment type, size, and manufacturer fixed effects. Market share is estimated for new equipment sales within a given equipment type. It is calculated annually and averaged over the life of the model. We base market share estimates only on bank financed sales in order to avoid capturing market share which is driven by aggressive captive financing terms.

We find that, even within a given manufacturer, models receiving captive support are more likely to be models with substantial market share. Although earlier work has suggested a relationship between firm size or market share and the use of captive finance (see Mian and Smith (1992) and Bodnaruk, Simonov, and O'Brien (2012)), we are able to exploit machine-level data to show that this relationship holds within manufacturer. This allows us to rule out explanations that would link market share and captive support indirectly through observed or unobserved manufacturer characteristics. Moreover, estimating market share within the universe of bank-financed machines eliminates the natural hypothesis that captive finance is causing market share.

Finally, column 2 puts these two results together to show that captive finance can only predict

the 95% confidence interval of the coefficient estimates from our baseline estimates. Details are reported in appendix Table A2.
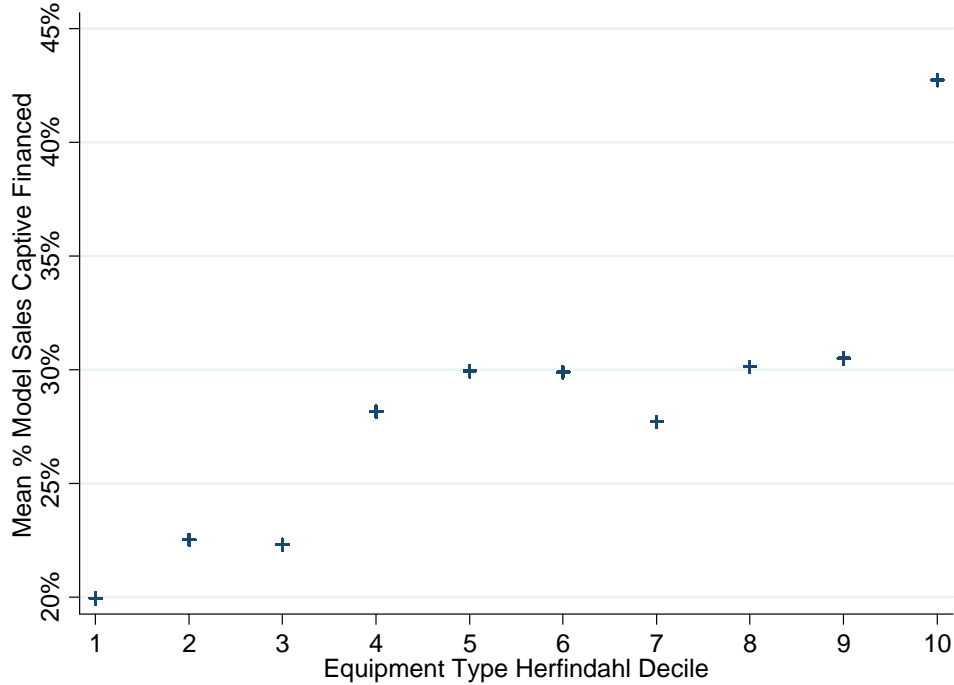
Figure 3: Captive Finance Intensity and Market Power. The figure plots the level of captive finance support received by an equipment model as a function of the concentration of the model's market. The vertical axis is the average percentage of new model sales financed by the manufacturer. The horizontal axis is the decile of the Herfindahl index for the model's machine type.

resale values when the manufacturer has market power. We replicate the regression of depreciation rates on *MODEL CAPTIVE SUPPORT* and controls for equipment type, size, and manufacturer, but add an interaction with a dummy variable for models with above-median market share. The interaction is negative and significant. For manufacturers with above-median market share for a given machine type, going from 0 to 100% captive finance of new sales reduces depreciation rates by 13 percentage points, versus a statistically insignificant reduction of 4 percentage points for manufacturers with below-median market share.

Of course, we can think about other mechanisms which would be consistent with the finding that captive-backed models depreciate more slowly. Perhaps manufacturers are better monitors of their collateral than bank lenders (Mian and Smith 1992). Affirmative covenants requiring routine maintenance, for example, may be cheaper or easier to enforce for manufacturers than for bank

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lenders. Alternatively, it might be the case that manufacturers signal high machine durability by providing financing, which in turn generates the correlation with higher resale values we observe in our data. Stroebel (2015) finds that when new homes are financed by the home builder, they are less likely to suffer capital losses. He convincingly links this result to better construction techniques. To be clear, while we acknowledge that captive finance may help resolve information asymmetry problems, the central prediction of the mechanism presented in our paper is that the manufacturer will maintain prices in secondary markets through its *ex-post* production choices, independent of chosen quality. Both mechanisms– those driven by hidden information and hidden action– may be independently important. Thus one challenge for us is to identify the predictions of our model that are unique.

The evidence from Table 2 is a start. A distinguishing prediction of our model is the interaction between market power, captive financing, and resale values; it is not clear that the role of captive finance in signaling product quality should drive differential effects on depreciation based on market power.

We can also, however, attempt to measure and control for ex-post machine quality using information on machine condition and age at the time of sale. If we can effectively control for ex-post measures of quality, that will help inform the extent to which this is an important aspect of captive financing and the lower depreciation rates associated with captive-backed machines. Table 3 attempts to isolate the purely financial depreciation effect related to captive financing from a "better machines" or "better maintenance" hypothesis.

We begin by generating an estimate of model durability using information on machine condition from the auction dataset. In particular, the data include a condition variable coded excellent, very good, good, fair, and poor based on a physical evaluation of the machines coming up at auction. We exclude machines for which the variable is missing or unknown. Because truly failed machines don't trade at auction, we define failure as a machine transitioning to fair or poor condition and use survival analysis to estimate a survival function for each model. Our survival function is estimated using an exponential model with a constant hazard for each model. Finally, as a measure of durability, we use the logged median survival time for a machine, backed out of the

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estimated survival function.[12] Because we only use estimates of durability for models with 30 or more observations for which condition is reported, we are left with just 879 models.

Columns 1 and 3 of Table 3 first re-estimate the relationship between captive finance support and depreciation, with and without manufacturer fixed effects, but on the more limited sample. This gives us a baseline against which to compare the partial effect of captive support on depreciation, controlling for durability. Columns 2 and 4 add durability as a control. In each case, the effect of captive finance on depreciation rates appears unaffected by the inclusion of durability as a control. That is, the mode of financing for a given make and model interacts with its depreciation rate independent of measures of ex-post quality.

Of course, the chosen measure of machine durability is likely to be noisy. While our measure of dollar depreciation is also estimated, and thus noisy, the noise is less worrisome when added to the dependent variable. Measurement error in an important control variable attenuates its measured effect on the regressand and thus limits its effectiveness as a control. Having said that, we are encouraged by two observations. First, log median survival time is very effective in predicting dollar depreciation rates. In each regression, it is highly significant (t-statistics near 6) and generates at least a modest increase in the regression r-squared. While this should not be surprising, it rules out the possibility that our measure of durability is pure noise. Second, as we add durability as a control, the effect of model captive support on dollar depreciation is all but unchanged. The fact that adding a noisy control does nothing to attenuate the coefficient of interest suggests that even a perfectly measured control would be unlikely to qualitatively change the results. We return to this issue again in the next section where we have a stronger test to control for machine characteristics, albeit for a limited sample of machines.

4.2   Evidence from Volvo's Acquisition of Ingersoll Rand Unit

Absent large-scale exogenous variation in the use of captive financing, we have done our best to show that the preponderance of the evidence supports a role for captive finance as a commitment mechanism for manufacturers with market power. The inclusion of manufacturer fixed effects in

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[12]The results are unchanged if we use the median survival time in levels.

Table 1 rules out alternative mechanisms having to do with unobserved manufacturer characteristics; controlling for a measure of the physical durability of machines in Table 3 indicates that asymmetric information about product quality is unlikely to be driving our results; and the results based on market power in Table 2 provide evidence of a prediction unique to our hypothesis.

Now we add to the evidence a case study of a set of machines which went from receiving no financing support from the manufacturer to substantial captive backing over a short period of time, and then examine their subsequent resale performance. While we won't argue that change in financing was randomly assigned, the motivations for the change in financing are at least readily understandable. Moreover, while financing patterns changed, the machines being produced were largely unchanged. This fact helps narrow the set of plausible interpretations of prior results.

Specifically, we focus on the acquisition of Ingersoll Rand's road construction division by Volvo in 2007. The road construction unit was part of Ingersoll Rand's construction technology division. Though a small part of the total firm, generating less than 10% of operating income in 2006 (Ingersoll Rand annual report 2006), the division was a large part of the road construction market, with 25% market share as of 2004, measured using new units financed in the UCC data. The sale to Volvo was driven by a strategic realignment that redirected resources to other divisions, including the larger climate control and security divisions. The proceeds from the $1.3BN sale were used to fund acquisitions and a continued share buyback program. The sale does not appear to have been driven by distress, but rather strategic fit for the two companies. Reuters' announcement provided the following commentary on the sale from Volvo's perspective: "In terms of products this is right. These are things they don't have in their product line-up. In terms of the price, you always pay quite a lot for these types of assets since they have rather high margins."[13]

Two aspects of the sale are of interest. First, the acquisition gives sharp variation in captive financing support. Whereas Ingersoll Rand was not historically active in financing, Volvo had a large consumer finance division that immediately began aggressively financing the formerly Ingersoll Rand machines. Second, until recently, the machines acquired and sold by Volvo were under the same designs and manufactured in the same plants as they had been when owned by Ingersoll

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[13] "Volvo to buy Ingersoll Rand Road unit for $1.3 BN," Reuters, February 27, 2007.

Rand. As an example, the specifications for the most popular Ingersoll Rand roller (the DD24) are listed in the appendix alongside the same key specifications for the Volvo DD24 roller. A side-by-side comparison suggests these are very nearly identical machines. Thus, when we study resale performance, physical characteristics of the machine or information asymmetry about those characteristics are unlikely to be material drivers of any changes in resale performance. That is, the unit sale helps us isolate the hypothesized role for captive financing from potentially confounding physical characteristics of bank financed vs. manufacturer financed machines.

Figure 4 documents key aspects of the acquisition. Using the UCC data, we plot the market share of Volvo and Ingersoll Rand compactors, colloquially described as steam rollers though now primarily run on diesel fuel. Compactors, designed to achieve a flat surface on soil, gravel, or pavement, are the key road construction product line affected by the transaction and covered in our data sets. In the first year after the acquisition, combined sales of Volvo/Ingersoll Rand compaction equipment captured in the UCC data represented 15% of the number of total machines sold, second only in market share to Caterpillar.

Notice the acquisition by Volvo is reflected gradually in the two firms' market shares. Sales of Ingersoll Rand branded compactors are replaced, except for new old-stock sales, with Volvo machines by 2009. The transaction, however, sharply increased captive financing of Ingersoll Rand road construction products from 1.5% in 2006 to 68% in 2008. As mentioned above, Volvo had an active financing arm, so it seems natural that it would extend financing to these machines as well. Notice, the increase in captive financing by Volvo predates even the introduction of Volvo branded compactors. We will use this fact to argue that the variation in financing was not coincident with changes in other machine characteristics.

Meanwhile, why was Ingersoll Rand less active in captive finance? While we can't say with certainty, we suspect this is related to the company's broader business strategy, of which construction equipment was a small part. At the time of the divestiture, Ingersoll Rand's largest divisions were producing climate control equipment and refrigeration units for buses and refrigerated trailers, along with grocery store refrigerated displays. They later used cash from the division sale to expand this brand with the acquisition of Trane heating and cooling systems and services. Whereas
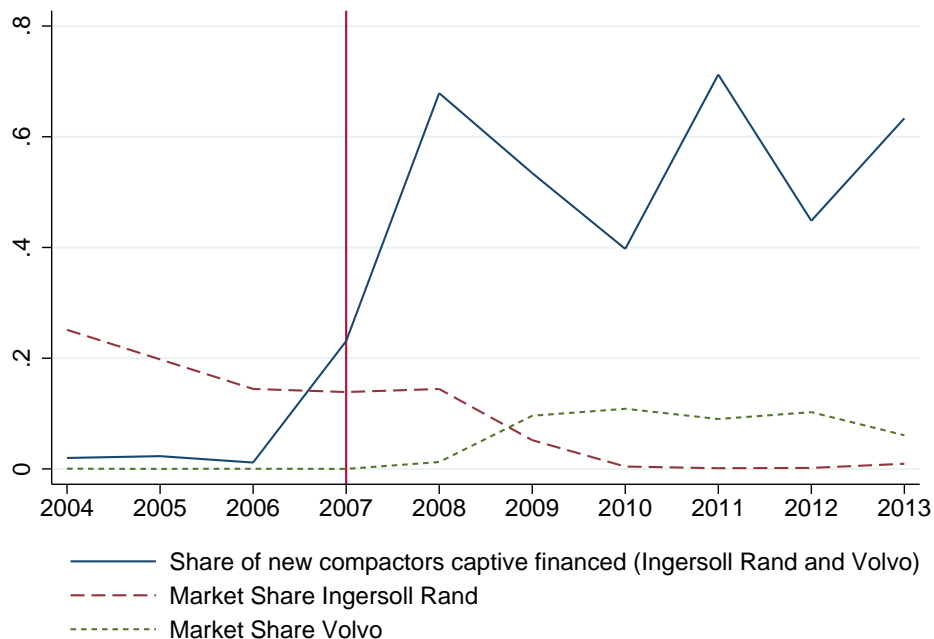
Figure 4: Ingersoll Rand sale of road construction equipment unit to Volvo. The figure plots the market share of new compaction equipment of Ingersoll Rand and Volvo (based on units financed in the UCC data) as well as the combined share of new machines which were financed by a captive.

our explanation for captive financing is intimately related to the ability to originate secured debt against the product being sold, for practical reasons, the primary products being sold by Ingersoll Rand would not appear to easily lend themselves to security interest. Meanwhile, there are limited opportunities for secondary markets in air conditioning systems. Thus, Ingersoll Rand's broader disinterest in captive financing is consistent with the model we have suggested.

Using the divestiture and resulting change in machine financing as a source of variation, Table 4 again tests for the relationship between machine depreciation and source of financing. The estimation strategy approximates a triple difference-in-difference whereby we estimate the impact of age on machine value for Ingersoll Rand machines before and after the acquisition of the business by Volvo. The difference in depreciation is then benchmarked against changes in depreciation observed for similar machines made by rival producers over the same time period.

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That is, we estimate the regression

$$ln(AuctionPrice) = \beta_1 ln(1 + MachineAge) + \beta_2 Post \times ln(1 + MachineAge) + \beta_3 IR \times Post$$

$$+\beta_4 IR \times ln(1 + MachineAge) + \beta_5 IR \times Post \times ln(1 + MachineAge) + \lambda Controls + \epsilon$$

where post is a dummy equal to one for machines sold at auctions in 2007 or after, and IR is a dummy for machines produced by Ingersoll Rand prior to 2007 and Volvo during and after 2007. The coefficient on $IR \times Post \times ln(1 + MachineAge)$ tells us whether or not Ingersoll Rand/Volvo machines depreciated differently post-divestiture relative to broader trends in machine depreciation over the pre and post periods (captured by $Post \times ln(1 + MachineAge)$). Notice, $Post$ is defined by the year of the auction and not the year the machine is produced. This is important because, unlike a depreciation effect driven by differences in how the machines were produced, which could only take effect for machines produced post-2007, the commitment to higher resale values induced by Volvo's increased role in financing should also benefit machines produced prior to 2007. In fact, we can (and do) test this specific prediction by limiting the sample to machines produced prior to 2007, for which depreciation rates can only be dictated by ex-post producer behavior and not ex-ante design or build choices by Volvo that differed from Ingersoll Rand.

Given that our auction data only go to 2013, we limit the analysis to post-2000 auction data, roughly balancing the sample around the 2007 handover. We also limit the age of the machines at auction to those less than 7 years old, given we only observe secondary sales of Volvo compactors up to this age. Finally, we control for the reported condition of the machine at auction when available, although for the majority of compactors, the condition is unknown. Condition is classified as excellent, very good, good, fair, poor, new, or unknown.

The results are reported in Table 4. Column 1 includes make-model fixed effects. Columns 2 and 3 include make-model-vintage fixed effects. Finally, column 3 excludes machines actually manufactured under Volvo ownership. That is, it reports how machines made by Ingersoll Rand depreciated before and after Volvo ownership.

In each case, the evidence is consistent with the prediction that the increase in captive financing

post-2007 changed how machines maintained their value over time. The coefficient on $IR \times Post \times ln(1 + EquipmentAge)$ ranges from 0.15 to 0.19 and suggests that following the acquisition by Volvo, machine depreciation slowed by 15-19% per doubling of machine age. The coefficient on $ln(1+EquipmentAge)$ in column 1 suggests a baseline 40% elasticity of machine price with respect to age for non-Ingersoll Rand/Volvo machines before 2007.[14] Again, the improvement in depreciation is relative to the change in depreciation of non-Ingersoll Rand/Volvo machines over the same time period (although this benchmarking is not critical, as there is no evidence that depreciation rates of road construction equipment changed for the control group from 2000-2006 vs. 2007-2013). Particularly striking is the evidence in column 3, which tells us that the improvement in depreciation rates is even observed for machines produced before the merger was announced. This would seem to rule out differences in ex-ante characteristics between Volvo and Ingersoll Rand machines driving the results in columns 1 and 2.

One aspect of the results that is notably inconsistent with our hypothesis is the sign and magnitude of the interaction between IR and the post-period dummy. Specifically, the interaction is negative in each specification, though it is only statistically significant in column 1. This coefficient tells us the relative change in value of Ingersoll Rand/Volvo machines when ln(1+Machine Age)=0, that is, when machines are brand new; the signs on our estimated coefficients tell us that brand new machines may have actually fallen in value relative to the control group going from the pre- to the post-period. Of course, the predicted effect of the increase in captive financing would have been higher prices across the board, including brand new machines, as commitment to higher resale values raises current prices.

While the sign on this secondary coefficient is not as predicted, inferring the effect of the acquisition on new machines by looking at auction data is based largely on interpolation at the edges of the machine age distribution. For example, 95% of the sample of Volvo or Ingersoll Rand road construction equipment is two years old or older. Just 1.65% of traded machines are less than one year old. Moreover, although there is not evidence of increased prices for new machines, the average

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[14]The coefficient on age is harder to interpret in columns 2 and 3, which include both model-vintage fixed effects and auction year dummies, which combined, are collinear with age and nearly collinear with ln(1+Machine Age). The results are robust to dropping time dummies and/or vintage fixed effects.

effect on prices is sharply positive; the marginal effect of the post-period on treated machines increased average prices by 5-9%, depending on the specification.[15] Thus the broader evidence would suggest that the acquisition and resulting increases in financing were associated with increased prices generally and slower depreciation.

4.3 Captive Finance and Pledgeability

While we find support for the notion that captive finance can be motivated by the desire to commit to high resale values for durable capital, perhaps the more interesting implication of this hypothesis is that captive financing allows for— or to be more precise, *requires*— lower down payments from the buyer, relaxing credit constraints for borrowers with limited internal cash. High loan-to-values provide commitment to the producer not to lower prices in the future, but if the captive's financing activities are observable to bank lenders, they may free-ride and extend the same loan-to-value without incurring excess risk of default. Thus, sufficient captive finance backing will generate lower down payments, even when machines are financed by banks. Whereas simply observing more aggressive lending standards by captives would perhaps not be surprising (suppose, for example, that captives are able to cross-subsidize loan losses with additional profits generated by aggressive lending), the prediction that banks will lend more on machines that receive large amounts of captive finance is a prediction unique to our model.

We test this prediction in Table 5 by using a relatively small subset of loans made by banks for which the lender reports the loan amount on their UCC filing. Combining loan value with an EDA-provided estimate of purchase price based on machine value at that point in time, we create a variable, $DOWNPAYMENT$, as the difference between the log purchase price and the log loan amount. Of interest is the effect of captive financing on predicted down payment amounts, controlling for machine characteristics as well as borrower characteristics. While borrower characteristics are limited, we observe the borrower's state and industry and include dummy variables for each (industry dummies are at the level of a 2-digit SIC code). For the machine, we can control for the equipment type, size, and the age of the machine, all of which may plausibly impact both

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[15]For example, using column 1, average ln(1+Machine Age) is 1.53. So the % change in value can be read off as the coefficient on $Post \times IR$ plus 1.53 times the coefficient on $Post \times IR \times ln(1+MachineAge)$ (-0.239+1.53*0.188=0.05).

the required down payment and the lender of choice. Finally, and most importantly, we limit our sample to individual machines which were financed by banks, but which otherwise received varying degrees of captive support. This ensures that any reported effect is not driven by differential credit standards of the captive.

Table 5 reports the results. We find the effect of captive financing support on down payments required by banks is large and significant. A model without captive support requires a down payment (as a fraction of value) which is 14% larger than a machine which is otherwise always financed by the captive. With 20% as a typical rule-of-thumb required down payment and average machine values of $89,455, this implies an additional $2,504 down payment amount required of machines receiving no captive support (relative to $17,891 for a fully captive financed model).

This result suggests a positive spillover effect of captive finance. While the reduced depreciation and higher resale values are clearly serving as rent seeking devices in the model, the resulting low required down payments/higher pledgeability of physical machines that have received captive financing support may be of value when credit constraints bind. While not formally considered in our hypothesis development, we now ask: can the outcomes from rent seeking generate positive spillover effects in periods when financing frictions, and thus the shadow value of pledgeable equipment, are high? If this is the case, the benefits from captive financing will also arise in the worst of times, providing a hedging role for captive finance. Benmelech and Bergman (2009), for example, show that pledgeability in the airline industry is most valuable during industry downturns when rationing is likely to be greatest.

To test this possibility, and to provide additional support for the argument that captive finance may help commit companies to production paths fostering greater pledgeability, we look to the revealed preference for makes and models receiving strong captive support during periods of extreme credit tightening by banks. Our prediction is that borrowers facing rising shadow costs of internal capital will choose machines with greater pledgeability— machines that have received captive financing support from their makers. Because we would like to avoid documenting substitution effects of bank financing being replaced by captive financing during periods of tight credit, we again limit our attention to the machine choice of borrowers who are financing their purchases with banks.

Figure 5 gives a taste of our findings. Using two measures of bank tightness, we observe a strong variable demand for machines with captive finance support during periods of tight credit. The top panel plots the probability a given new machine purchase, when financed by a bank, will be of a make and model that received strong captive finance support over the entire sample period. We define machines as receiving strong captive support when the the fraction of total machines financed by the manufacturer is more than 50%.[16] This series (the solid line) is plotted against a dashed line representing a survey-based measure of banks' demand for pledgeable assets taken from the senior loan officer survey performed quarterly by the Federal Reserve Board of Governors. The survey asks loan officers whether they have tightened or loosened collateral requirements for small businesses. The Fed then reports the net percentage reporting tightening (percentage tightening minus percentage loosening). There is an apparent correlation between the two time series driven by large changes during boom and busts periods, but also in the quarterly changes. (The correlation between the two series is 0.38, and the correlation between the first-differenced series is 0.23). The bottom panel, meanwhile, shows a similar relationship between machine choice and tightening as seen via increases in loan spread. The dashed line represents the mean spread over Libor of new issue speculative grade loans in the DealScan database. Again, in periods of tight credit/high spreads, the demand for machines with captive finance support increases, even among bank financed purchases. Limiting to bank financed purchases only, meanwhile, rules out that the pattern is driven by time series variation in the relative availability of bank vs captive finance to customers.

Table 6 reduces the picture in Figure 5 into a regression of an individual purchaser's machine choice on financing conditions, this time allowing for the sale of new and used goods as well as controls for machine age, type, and size. We are also concerned that the recent credit crunches may have disproportionately affected industries that use machines receiving more captive support. As a result, we include both 2-digit SIC industry and state fixed effects for machine buyers. Meanwhile, the left hand side variable is again the familiar measure of a make and model's captive finance support estimated over the entire sample for models with more than 30 observations.

Column 1 reports the basic finding from Figure 5 that buyer preference for machines receiving

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[16]To be explicit, we plot the quarterly time fixed effects from a regression of machine choice (captive supported machine or not) on quarter, equipment size, and equipment type fixed effects.
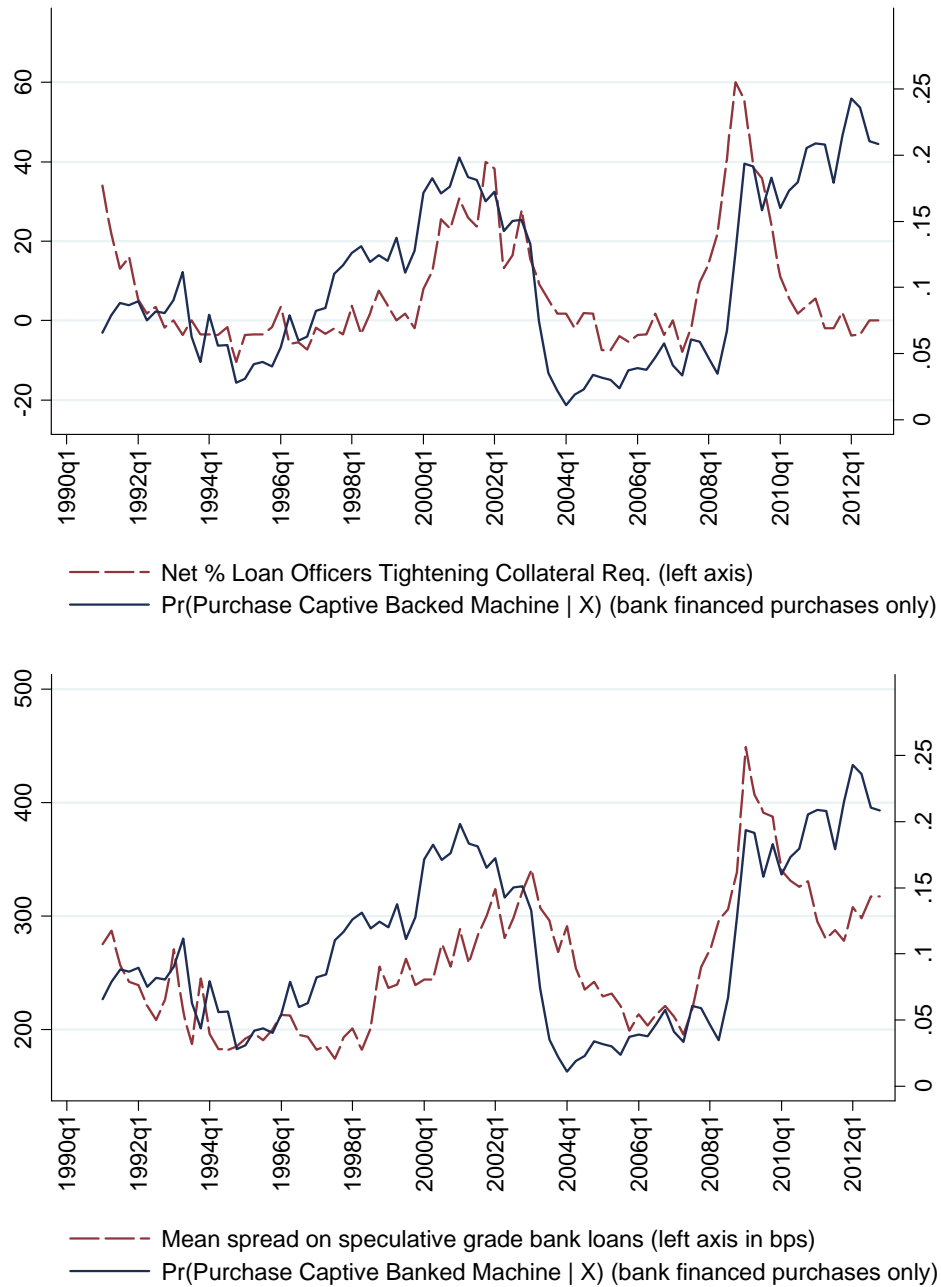
Figure 5: Machine Choice and Credit Tightness. The figure plots the time series of the proportion of new, bank-financed purchases of models with high captive support (more than 50% of machines captive financed) on the right-hand axis of both panels. In the first panel, we compare this to the net percentage of loan officers that reported tightening collateral requirements on the left-hand axis. In the second panel, we plot the mean spread on speculative grade bank loans on the left-hand axis.

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captive support increases during periods of credit tightness, even among bank-financed purchases. Because we estimate the captive finance support the buyer's chosen model has received over the entire sample (and because it is stubbornly persistent within models), this is unlikely to be an artifact of relatively more captive financing being available in periods of tight bank credit. However, to rule this out formally, we add the quarterly mean percentage of purchases financed by captives to the right hand side. The results from column 1 remain significant and do not attenuate. This is due to the fact that captive financing does not appear to be crowded out during periods of loose bank credit, nor was it a major substitute during the crisis. If anything, captives have been generally more sensitive to changes in lending standards reported by banks than the banks themselves. Benmelech, Mesenzahl, and Ramcharan (2015) exploit an acute example of this in the financial crisis.

Of course, periods of credit tightness covary closely with other business cycle measures. As a result, it may be reasonable to interpret this pattern loosely as a preference for captive financed machines in downturns generally and not necessarily as evidence of a direct link to credit frictions. Moreover, we are sensitive to the fact that, while the time-series results appear statistically significant under our best conservative standard error estimates, we only have data over a few credit cycles.

5   Discussion

A simple model of a durable goods manufacturer operating with pricing power suggests that the act of financing one's own sales may provide a commitment to support higher resale values in the future, and as a result, lower down payments today. We have found support for both those predictions in the data, as well as the corollary predictions which emerge outside of the model, that captive financed products will become favored by borrowers when access to funding is constrained.

The welfare implications of captive finance, therefore, are blurred. On one hand, the evidence points to captive finance as a rent seeking device. Manufacturers that offer it would appear to do so, at least in part, to raise prices today and restrict production tomorrow. This has a clearly negative impact on consumer surplus. On the other hand, in a world with credit constraints where

pledgeability is valuable, welfare implications become less clear. As we saw in the crisis (Figure 5), the demand for machines offering greater pledgeability appears to jump exactly when the need for lending was greatest. This suggests a value to captive finance which is perhaps largest in the worst states. Thus, it may be reasonable from a welfare context to think of captive finance as a costly hedge, where the cost of restricted supply and the associated manufacturer rents afford the benefit of relaxed credit constraints on capital investment during periods of tight credit.

Appendix

Appendix A   Equilibrium with Captive and Bank Financing

Empirically we observe that most machine types are neither purely captive nor purely bank financed. In many of our empirical tests, we will divide machine types into high and low captive support. In order to support the empirical analysis, we now analyze the optimal financing contract when (for exogenous reasons) the manufacturer finances a fraction α of the machines it produces and banks finance the remaining machines. Financing only a fraction of the machines will limit the manufacturer's ability to commit to high resale prices. What is the highest second period price a manufacturer can commit to when it finances a fraction α of the machines? If the manufacturer were to fully internalized the second-period price of the machines it finances, it would face the problem

$$\max_{q_2} \quad p_2(q_2) \cdot q_2 + p_2(q_2) \cdot \alpha q_1. \tag{6}$$

The first term in (6) captures the manufacturer's proceeds from second-period production, while the second term captures the manufacturer's exposure to resale prices. The first-order condition and associated price are:

$$q_2^* = \frac{1}{2b}(a - bq_1(1 + \alpha)), \qquad\qquad p_2^* = \frac{1}{2}(a - bq_1(1 - \alpha)) \tag{7}$$

Substituting this into the manufacturer's first-period problem, it must solve:

$$\max_{q_1} \quad p_1(q_1) \cdot q_1 + \pi_2^*, \tag{8}$$

where $\pi_2^* = p_2^* \cdot q_2^*$. Taking first-order conditions gives the following solution:

$$
\begin{aligned}
q_1^* &= \frac{2a}{b(5 - 2\alpha + \alpha^2)}, \qquad p_1^* = \frac{a}{2}\left(\frac{9 - 4\alpha + 3\alpha^2}{5 - 2\alpha + \alpha^2}\right), \quad \pi^* = \frac{a^2}{4b}\left(\frac{9 - 2\alpha + \alpha^2}{5 - 2\alpha + \alpha^2}\right) \\
q_2^* &= \frac{a}{2b}\left(\frac{3 - 4\alpha + \alpha^2}{5 - 2\alpha + \alpha^2}\right), \quad p_2^* = \frac{a}{2}\left(\frac{3 + \alpha^2}{5 - 2\alpha + \alpha^2}\right).
\end{aligned}
\tag{9}
$$

The financing contract that achieves this solution is given by setting the loan size, d_2, equal to the desired second-period price, p_2. Thus, the financing contract is given by

$$d_1^* = a \left(\frac{3 - 2\alpha + \alpha^2}{5 - 2\alpha + \alpha^2} \right), \qquad\qquad d_2^* = \frac{a}{2} \left(\frac{3 + \alpha^2}{5 - 2\alpha + \alpha^2} \right). \tag{10}$$

The manufacturer's profit is strictly increasing in the proportion of machines it finances internally. Similarly, the depreciation rate and the down payment required are strictly decreasing in the proportion of machines financed internally. Thus we expect to see that when manufacturers finance a larger fraction of their machines, the machines depreciate more slowly and the lender is able to give larger loans.

Appendix B   Machine Types and Manufacturers

Table A1: Machine Types and Manufacturers. We report the top 10 equipment types and manufacturers from the UCC filing data. Included are both new and used sales from 1990-2012. Ranking is based on number of observations.

	(1) Top 10 Machine Types	(2) Top 10 Manufacturers
1	SKID STEER LOADERS	CATERPILLAR
2	EXCAVATORS	DEERE
3	CRAWLERS	CASE
4	INDUSTRIAL TRACTORS	BOBCAT
5	WHEEL LOADERS	KOMATSU
6	ROUGH TERRAIN FORKLIFTS	NEW-HOLLAND
7	COMPACTORS	INGERSOLL-RAND
8	TRENCHERS	VOLVO
9	AERIAL LIFTS	DITCH-WITCH
10	DRILLS	FORD

Appendix C Ingersoll Rand vs. Volvo DD-22/24 Compactors

Introducing reliable performance in a smaller package

Ingersoll Rand combined our global engineering resources to bring you the DD-22 and DD-24 vibratory asphalt compactors. Offering high productivity and unsurpassed value, these machines feature industry-leading drum performance, superior propulsion characteristics, and unmatched operation intervals in a class-leading 2.5-tonne machine. Designed for optimum compaction of complex materials, the DD-22 and DD-24 provide high performance in a small package. Move your business and bottom line in the right direction with the DD-22 and DD-24.

MODEL		DD-22	DD-24
MACHINE WEIGHTS			
Operating Weight – lb (kg)		5,400 (2450)	5,725 (2600)
Weight @ Front Drum – lb (kg)		2,700 (1125)	2,863 (1300)
Weight @ Rear Drum – lb (kg)		2,701 (1125)	2,863 (1300)
Shipping Weight – lb (kg)		5,070 (2300)	5,400 (2450)
MACHINE DIMENSIONS			
Length – in (mm)		95 (2420)	95 (2420)
Width – in (mm)		39.4 (1000)	47.2 (1200)
Height (top of steering wheel) – in (mm)		75 (1909)	75 (1909)
Height (top of ROPS / FOPS) – in (mm)		103 (2621)	103 (2621)
Drum Base – in (mm)		68 (1720)	68 (1720)
Curb Clearance – in (mm)		9.8 (250)	9.8 (250)
Inside Turning Radius (to drum edge) – in (mm)		110 (2800)	104 (2650)
DRUM			
Width – in (mm)		39 (1000)	47 (1200)
Diameter – in (mm)		28 (700)	28 (700)
Shell Thickness – in (mm)		0.5 (13)	0.5 (13)
Finish		Machined	
VIBRATION			
Frequency – vpm (Hz)		3,300 / 4,020 (55 / 67)	3,300 / 4,020 (55 / 67)
Nominal Amplitude – in (mm)		0.02 (0.53)	0.02 (0.53)
Centrifugal Force – lb (kN)	High	8,318 (37)	8,992 (40)
	Low	5,620 (25)	6,295 (28)
PROPULSION			
Type		Closed-loop hydrostatic	
Drum Drive		Radial piston	
Travel Speed – mph (km/h)		0 – 6.2 (0 – 10)	0 – 6.2 (0 – 10)
ENGINE			
Make / Model		Cummins A1700	Cummins A1700
Engine Type		3-cylinder diesel	
Rated Power @ 2,500 rpm – hp (kW)		32 (24)	32 (24)
Electrical		12 V, 45 A alternator	
BRAKES			
Service		Hydrostatic	
Parking Secondary		Spring-applied, hydraulic release on each drum	
WATER SYSTEM			
Type		Pressurized	
Pumps		Electric diaphragm	
Spray Bars		1 per drum, PVC	
Nozzles		4 per spray bar	
Filtration		Inlet and nozzle filtration	
Drum Wipers		Spring-loaded, self-adjusting neoprene wipers	
Water Tank Capacity – gal (L)		68 (260)	68 (260)
MISCELLANEOUS			
Articulation Angle		+ / - 30°	+ / - 30°
Oscillation Angle		+ / - 10°	+ / - 10°
Fuel Tank Capacity – gal (L)		10.6 (40)	10.6 (40)
Hydraulic Oil Capacity – gal (L)		7.1 (27)	7.1 (27)
Gradeability (theoretical)		30%	30%

Product improvement is a continuing goal at Ingersoll Rand. Designs and specifications are subject to change without notice or obligation.

SERVICEABILITY

Unobstructed daily checkpoints, easy-to-lift engine enclosure, plus ground-level access to the engine, radiator, battery, and filters. Color-coded service charts show detailed checkpoints, service intervals, and proper lubricants.

PERFORMANCE FEATURES

- Dual amplitude drums
- Excellent visibility to drum edges at front and rear of machine
- High frequency (over 4,000 vpm) allows for maximum rolling speeds
- Liquid cooled 32-hp, 3-cylinder diesel engine
- Neoprene wipers to keep water on drum surface
- Pressurized water system with flow control; 4 nozzles per drum

AVAILABLE OPTIONS

- Biodegradable oil
- Dual drive levers
- Edge compactor and cutter
- Foldable ROPS assembly
- Hydraulic traction control
- Inside neoprene wipers
- Offset articulation joint (50 mm)
- Work and road light packages

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Figure A1: 2006 Ingersoll Rand DD-22/24 Compactor Spec Sheet.

SPECIFICATIONS

Model		DD22		DD24	
Machine Weights (w/ ROPS)					
Operating Weight	kg (lb)	2 450 (5,400)		2 600 (5,725)	
Weight @ Front Drum	kg (lb)	1 225 (2,700)		1 300 (2,863)	
Weight @ Rear Drum	kg (lb)	1 225 (2,700)		1 300 (2,863)	
Shipping Weight	kg (lb)	2 300 (5,070)		2 450 (5,400)	
Machine Dimensions					
Length	mm (in)	2 420 (95)		2 420 (95)	
Width	mm (in)	1 090 (43)		1 290 (51)	
Height (top of steering wheel)	mm (in)	1 909 (75)		1 909 (75)	
Height (top of ROPS)	mm (in)	2 624 (103.3)		2 624 (103.3)	
Drum Base	mm (in)	1 720 (68)		1 720 (68)	
Curb Clearance	mm (in)	490 (19.3)		490 (19.3)	
Inside Turning Radius (to drum edge)	mm (in)	2 800 (110)		2 700 (106)	
Drum					
Width	mm (in)	1 000 (39)		1 200 (47)	
Diameter	mm (in)	700 (28)		700 (28)	
Shell Thickness	mm (in)	13 (0.5)		13 (0.5)	
Finish		Machined			
Vibration					
Frequency	Hz (vpm)	55 / 67 (3,300 / 4,000)		55 / 67 (3,300 / 4,000)	
Nominal Amplitude	mm (in)	0,53 (0.02)		0,53 (0.02)	
Centrifugal Force	kN (lb) High	37 (8,318)		40 (8,992)	
	Low	25 (5,620)		28 (6,295)	
Propulsion					
Type		Closed-loop hydrostatic			
Drum Drive		Radial piston			
Travel Speed	km/h (mph)	0 – 10 (0 – 6.2)		0 – 10 (0 – 6.2)	
Engine					
Make / Model		Cummins A1700			
Engine Type		3-cylinder diesel			
Rated Power @ Installed Speed	kW (hp)	24 (32)		24 (32)	
Electrical		12 volts, 45 A alternator			
Brakes					
Service		Hydrostatic			
Parking Secondary		Spring-applied, hydraulic release on each drum			
Water System					
Type		Gravity	Pressurized	Gravity	Pressurized
Nozzles		–	4 per drum	–	4 per drum
Filtration		Inlet filter	Inlet and nozzle filtration	Inlet filter	Inlet and nozzle filtration
Drum Wipers		Spring-loaded, self-adjusting urethane wipers		Spring-loaded, self-adjusting urethane wipers	
Water Tank Capacity	l (gal)	225 (59)	260 (68)	225 (59)	260 (68)
Miscellaneous					
Articulation Angle		+ / - 30°		+ / - 30°	
Oscillation Angle		+ / - 10°		+ / - 10°	
Fuel Tank Capacity	l (gal)	40 (10.6)		40 (10.6)	
Hydraulic Oil Capacity	l (gal)	27 (7.1)		27 (7.1)	
Gradeability (theoretical)		30%		30%	

Product improvement is a continuing goal at Volvo. Designs and specifications are subject to change without notice or obligation.

Figure A2: 2008 Volvo DD-22/24 Compactor Spec Sheet.

Appendix D   Model-year Level Observations – Robustness

Here we preset an alternative version of our main test in which we treat a given model-year (as opposed to model) as the unit of observation. For example, we can compare the price path of a 2000 John Deere 310G loader backhoe with a 2001 John Deere 310G loader backhoe. We estimate depreciation rates in a similar fashion as before. We then project that depreciation rate on a backward-looking measure of captive support for the model, taken from prior years' captive financing share for the same model. This has the benefit of allowing captive support to vary over time and allows us to include time fixed effects in the model to remove time trends from the variation in captive financing. It also eliminates the potential for forward-looking variation in captive financing to drive our results, although it is not clear that that is necessary. After all, our hypothesis would suggest that even future extension of captive financing will result in better resale performance of current machines.

We restrict the sample to those model-years for which we have more than 30 auction observations and more than 30 UCC observations with which to calculate captive support, leaving us with 45 manufactures (vs. 102 in Table 1), 689 models (vs. 1732 in Table 1), and 2,375 model-year observations.

Using this alternative approach, we find similar results, albeit with attenuated coefficients. The attenuation is not necessarily surprising, given that the time varying measure of captive financing support is considerably noisier (and has a larger standard deviation) than the model-level estimate from Table 1. Even then, the coefficients fall within the 95% confidence interval of the coefficient estimates from our baseline estimates.

Table A2: Captive finance and resale prices at the model-year level–robustness. The table provides an alternative construction to the tests presented in Table 1, in which we estimate average depreciation rates of machines based on their make, model, and vintage (year built) rather than make and model. Depreciation rates are estimated for each make and model and year built (conditional on having 30 or more resale observations) based on the following regressions:

$$ln(\widetilde{AuctionPrice}_{i,t}) = \alpha_{modelyear} + \delta_{modelyear}ln(1 + \widetilde{EquipmentAge}_{i,t}) + \epsilon_{i,t}$$

where subscript i indexes an individual machine and t is the year of the auction. Year fixed effects are estimated in the full auction sample and partialled out of age and price in a first stage regression. Equipment age is the number of years between the original manufacture date and the date of resale. $-\delta_{modelyear}$, the model-year specific depreciation rate, captures the percentage loss in value for proportional increases in age. Model-year depreciation rates are regressed on a rolling estimate of captive support for a given model. We calculate the variable model captive support as the fraction, on a rolling, backwards-looking basis, of new sales financed by captives in all prior years for the same model. Also distinct from Table 1 of the main paper, we are able to now include model-year fixed effects in the regression. Standard errors are clustered at the manufacturer level, are robust to heteroskedasticity, and are reported in parentheses. ***, **, and * signify results significant at the 1, 5, and 10% levels, respectively.

	(1) Depreciation Rate (model-year)	(2) Depreciation Rate (model-year)
Model Captive Support	-0.06**	-0.12**
	(0.03)	(0.05)
Manufacturer Fixed Effects	NO	YES
Equipment Type Fixed Effects	YES	YES
Equipment Size Fixed Effects	YES	YES
Model Year Fixed Effects	YES	YES
Observations	2375	2375
R-squared	0.45	0.49

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Table 1: Captive finance and resale prices. The table documents the relationship between the resale value of heavy machinery and the extent of captive financing in the primary market. Depreciation rates are estimated for each make and model (conditional on having 30 or more resale observations) based on the following regressions:

$$ln(\widetilde{AuctionPrice}_{i,t}) = \alpha_{modelyear} + \delta_{modelyear}ln(1 + \widetilde{EquipmentAge}_{i,t}) + \epsilon_{i,t}$$

where subscript i indexes an individual machine and t is the year of the auction. Year fixed effects are estimated in the full auction sample and partialled out of age and price in a first stage regression. Equipment age is the number of years between the original manufacture date and the date of resale. $-\delta_{model}$, the model-specific depreciation rate, captures the percentage loss in value for proportional increases in age. Columns 1 and 2 report regressions of depreciation rate on the fraction of new machines which are financed by captive finance units for each model, along with controls for equipment subtype and size,

$$-\delta_{model} = \alpha + \beta_1 ModelCaptiveSupport + \beta_{2...k}Controls_{model} + \epsilon.$$

Model Captive Support is calculated by model from the UCC filing data and is only included for models which had 30 or more machines financed from 1990-2012. Standard errors are clustered at the manufacturer level, are robust to heteroskedasticity, and are reported in parentheses. ***, **, and * signify results significant at the 1, 5, and 10% levels, respectively.

	(1) Depreciation Rate	(2) Depreciation Rate
Model Captive Support	-0.14***	-0.18***
	(0.05)	(0.07)
Manufacturer Fixed Effects	NO	YES
Equipment Type Fixed Effects	YES	YES
Equipment Size Fixed Effects	YES	YES
Observations	1727	1727
R-squared	0.45	0.55

Table 2: Captive finance and market power. Column 1 estimates the link between market share for a particular model and the extent to which that model receives captive support. Market share is estimated for new equipment sales within a given equipment type. It is calculated annually and averaged over the life of the model. Market share estimates are based on bank financed sales. This helps us avoid capturing market share which is driven by aggressive captive financing terms. Column 2 extends the regressions of Table 1 to include an interaction term with a measure of model-specific market share. *High Market Share* is a dummy variable equal to one if a model is above the median market share in the sample. Sample size is somewhat larger than in Table 1, where only models with more than 30 recorded sales were included in the analysis. Below, we include these models so as not to exclude models with low market share (the variable of interest). All regressions include manufacturer fixed effects. Standard errors are clustered at the manufacturer level, are robust to heteroskedasticity, and are reported in parentheses. ***, **, and * signify results significant at the 1, 5, and 10% levels, respectively.

	(1) Model Captive Support		(2) Depreciation Rate
ln(Market Share)	0.03***	Model Captive Support	-0.04
	(0.01)		(0.06)
		Model Captive Support x High Market Share	-0.09**
			(0.04)
		High Market Share	0.05**
			(0.02)
Manufacturer Fixed Effects	YES		YES
Equipment Type Fixed Effects	YES		YES
Equipment Size Fixed Effects	YES		YES
Observations	2400		2399
R-squared	0.62		0.46

Table 3: Durability and captive finance. The table documents the relationship between machine durability and captive financing in the primary market. Durability is estimated for each make and model as the log median survival time (in years). Since actual machine failure is not observable, we instead treat a machine failure as moving from good to fair or poor condition. The survivor function is estimated in the auction data using an exponential model with a constant hazard for each machine, and median survival time is the value at which the survivor function equals 0.5. Columns 1 and 3 repeat the regressions from Table 1 for the limited sample of machines for which we can measure durability. Columns 2 and 4 then add durability as a control. Errors are clustered at the manufacturer level, are robust to heteroskedasticity, and are reported in parentheses. ***, **, and * signify results significant at the 1, 5, and 10% levels, respectively.

	(1) Depreciation Rate	(2) Depreciation Rate	(3) Depreciation Rate	(4) Depreciation Rate
Model Captive Support	-0.14***	-0.14***	-0.21***	-0.24***
	(0.04)	(0.05)	(0.05)	(0.06)
Durability		-0.09***		-0.08***
		(0.01)		(0.01)
Manufacturer Fixed Effects	NO	NO	YES	YES
Equipment Type Fixed Effects	YES	YES	YES	YES
Equipment Size Fixed Effects	YES	YES	YES	YES
Observations	878	878	878	878
R-squared	0.58	0.60	0.66	0.68

Table 4: Ingersoll Rand unit sale and resale performance. The table estimates the impact of Ingersoll Rand's sale of its road construction equipment unit to Volvo and the related increase in captive financing that followed on the depreciation of machines sold at auction. IR is a dummy for machines made by Ingersoll Rand prior to 2007 and made by Volvo in 2007 and after. Post2007 is a dummy for auctions sales occurring in 2007 or after. The interaction of Post2007 X IR X ln(1+MachineAge) documents the change in depreciation of formerly Ingersoll Rand-made machines after the acquisition, relative to similar machines during the same time period. Column 1 includes make-model fixed effects. Columns 2 and 3 include make-model-vintage fixed effects. Column 3 is limited to machines made prior to 2007. Standard errors are in parentheses and are clustered at the level of the manufacturer. ***, **, and * signify results significant at the 1, 5, and 10% level, respectively.

	(1) ln(Machine Price)	(2) ln(Machine Price)	(3) ln(Machine Price)
ln(1+MachineAge)	-0.40***	0.13*	0.12
	(0.03)	(0.08)	(0.08)
Post2007 X ln(1+MachineAge)	0.01	0.21**	0.17
	(0.06)	(0.08)	(0.13)
IR X ln(1+MachineAge)	-0.08***	-0.04	-0.04
	(0.03)	(0.05)	(0.05)
Post2007 X IR	-0.24**	-0.14	-0.18
	(0.10)	(0.10)	(0.13)
Post2007 X IR X ln(1+MachineAge)	0.19***	0.15**	0.17**
	(0.06)	(0.07)	(0.09)
Make X Model Fixed Effects	YES	NO	NO
Make X Model X Year Built Fixed Effects	NO	YES	YES
Year Fixed Effects	YES	YES	YES
Condition Fixed Effects	YES	YES	YES
Observations	13,257	11,781	10,422
R-squared	0.15	0.14	0.15

Table 5: Captive finance and pledgeability. The table estimates the effect of captive financing support at the model level on the down payment required for individual machine buyers via the following regression:

$$Downpayment = \alpha_{year} + \beta_1 CaptiveSupport_{model} + \beta_{2...k} MachineControls + \beta_{k+1...j} BorrowerControls + \epsilon$$

The variable *Downpayment* is reported as the difference between log ratio of estimated machine value to loan value. The model is estimated for bank financed purchases only. Standard errors are clustered at the manufacturer and year level, are robust to heteroskedasticity, and are reported in parentheses. ***, **, and * signify results significant at the 1, 5, and 10% levels, respectively.

Downpayment	
Model Captive Support	-0.142**
	(0.07)
Borrower Controls (state fixed effects, industry fixed effects)	YES
Machine Controls (type fixed effects, ln(age), size fixed effects)	YES
Observations	23,436
R-squared	0.27

Table 6: Machine choice and pledgeability in the time series. The table estimates the relationship between the yearly changes in collateral requirements reported by senior loan officers and the machine choice of bank-financed buyers, where machines are characterized based on their full history of captive support. Specifically, we estimate

$$ModelCaptiveSupport = \beta_1 \sum_{i=0}^{3} CollateralTightening_{t-i} + \beta_{2...k} MachineControls + \beta_{k+1...j} BorrowerControls + \epsilon$$

ModelCaptiveSupport represents the percentage of machines of the given model which are financed by a captive. Collateral tightening reflects the net percentage of loan officers responding to the survey reporting tighter collateral requirements on commercial loans to small and medium sized firms during the year of purchase. As in other tables, the measure of captive support is estimated at the model level and does not vary over time. Reported right-hand-side variables are demeaned and given unit standard deviation for ease of interpretation. The sample is limited to purchases of machines financed by banks. Column 2 includes a control for the fraction of machines financed by captives in a given quarter. Standard errors are clustered at the manufacturer and year level, are robust to heteroskedasticity, and are reported in parentheses. ***, **, and * signify results significant at the 1, 5, and 10% levels, respectively.

Chosen Model Captive Support	(1)	(2)
Collateral tightening over past year	0.015**	0.016***
	(0.006)	(0.005)
% machines financed by captives		-0.012**
		(0.005)
Borrower Controls (state fixed effects, industry fixed effects)	YES	YES
Machine Controls (type fixed effects, ln(age), size fixed effects)	YES	YES
Observations	985,830	985,830
R-squared	0.31	0.31