Collateral Damage: Low-Income Borrowers Depend on Income-Based Lending

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ABSTRACT

We use negative durability shocks from vehicle discontinuations to study the relative importance of asset-backed lending (ABL) and income-based lending (IBL) in auto finance. Discontinuations lead to increased down payments and loan-to-value ratios. Consumers who default on discontinued cars supply larger personal recoveries. These results all indicate that economically disadvantaged consumers are relatively more reliant on unsecured IBL, which stands in stark contrast to corporate financing patterns. We further show that vehicle recoveries on discontinued cars are lower for those borrowers who purchase after discontinuations, implying that depreciation is partially borrower-dependent. Our findings suggest that the securitization-driven rise of ABL may hamper the relative credit access of IBL-reliant lower-income borrowers.

JEL Classification: G51, G23

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Two key forces animate the auto financing market: asset-backed lending (ABL) linked to the physical collateral value of the vehicles (Assunçao et al., 2014; Argyle et al., 2021; Ratnadiwakara, 2021) and income-based lending (IBL) supported by a car buyer's income (Dewatripont and Tirole, 1994; Holmstrom and Tirole, 1997). In this paper we ask whether low-income borrowers rely relatively more on ABL or IBL. A clear understanding of the parts played by ABL and IBL in facilitating auto financing for economically disadvantaged consumers serves two functions. First, it provides insights into which financial innovations are likely to aid low-income borrowers. Second, given that incomes and asset prices move according to varying dynamics, it helps in predicting the relative impact on low-income borrowers of economic fluctuations that, for example, result in higher asset prices while leaving incomes largely unchanged. Our main finding is that IBL is particularly important for low-income borrowers. Even though these borrowers have limited wages, they nonetheless rely more heavily on IBL than ABL because they purchase assets with very low liquidation values, even when compared to their incomes. This stands in stark contrast to the corporate lending market, in which it is well-understood that secured ABL is crucial for the financing of resource-constrained firms (Leeth and Scott, 1989; John et al., 2003; Jimenez et al., 2006; Lian and Ma, 2021).

IBL is supported by a lender's ability to seize a portion of a borrower's future income via a mechanism such as wage garnishment. ABL relies on a lender's legal right to repossess an asset. Car loan contracts do not explicitly assign weights to the ABL and IBL components of the financing. ABL and IBL are thus intertwined, which presents challenges when empirically assessing the importance of IBL for auto finance across different types of borrowers.

To distinguish these two types of lending, we develop a theory showing that they respond differently to changes in the economic durability of the underlying physical asset: we describe an asset as declining in economic durability if it experiences both a a quicker rate of price depreciation over time and a lower price today. In an ABL-only model, for a given borrower, a decrease in economic durability decreases the loan-to-value (LTV) ratio (Hart and Moore, 1994) and also decreases the borrower's down payment (Rampini, 2019), as the asset becomes both less capable of supporting debt and less expensive.

By contrast, in a model that also incorporates IBL and the potential for changing borrower composition, a decrease in economic durability may *increase* both the down payment and the LTV. Down payments may be higher for less durable assets because they are purchased by low-income borrowers who have limited future wages to pledge to support borrowing today. Less durable assets have lower prices, so the presence of higher down payments for these assets implies that they are purchased with lower dollar values of debt. Less durable assets, however, also have lower collateral values. We show that if low-income borrowers rely relatively more heavily on IBL than ABL to finance their purchases, then loan amounts for less durable assets (largely supported by IBL) may decrease proportionately less than the decline in collateral values. As a result, LTV values may be higher for less durable assets. Under these conditions, disadvantaged borrowers have somewhat less income to pledge, but they purchase assets with dramatically lower collateral values.

It is therefore an implication of the model that if less durable assets have higher LTVs and down payments, then it must be the case that low-income borrowers depend more heavily than high-income borrowers on IBL. The predictions of the model provide an opportunity to empirically assess the importance of IBL for auto lending for different kinds of borrowers.

Testing these differing hypotheses requires a shock to economic durability. While cars may vary in their durability for a number of reasons (e.g., manufacturing, mileage), these sources of variation are also associated with differences along other dimensions (e.g., driving experience and amenities). We wish to identify the pure effect of a change in economic durability, so we seek shifts in durability that do not have an impact on current vehicle quality. We utilize model and make discontinuations on existing cars as shocks to durability. We match our data to over two hundred car model discontinuations and eight make discontinuations. Discontinuations may affect economic durability in two ways. First, it is likely that the physical durability of discontinued cars declines. Repair costs relative to vehicle value are of first-order importance in keeping a car on the road (Insurance Networking News, November 15, 2015) and discontinuation plausibly reduces vehicle durability of existing cars due to concerns about future parts and service expertise (Titman, 1984).[1] The inability to get replacement parts and increased servicing costs is frequently cited as

[1]While many internal components (e.g., transmission components) can be interchangeable across makes within the same car family (e.g., a Chevrolet part can be used in a GMC), it is not universally true for

a concern following the discontinuation of a car brand or model.[2] Second, discontinued cars may experience a loss of prestige, which should depress their current prices, which is another component of economic durability, though it is less clear whether this effect will also cause quicker value depreciation over time.

We begin our empirical analysis by showing that discontinuations do indeed reduce economic durability. We study data on used car prices from a broad set of wholesale auctions and find that annual depreciation is 1.2 percentage points per year higher for discontinued vehicles. Six years after discontinuation, the effect grows to 3.3 percentage points per year. We also show that after the announcement of discontinuation, car values fall by about $1068, which is a substantial drop relative to the mean wholesale value of $13636.

We then turn attention to a separate data set of loan originations to consumers and confirm that discontinued vehicles drop in value. We further find that default recoveries (the value the lender receives from the vehicle liquidation after default over the vehicle's wholesale value at origination) decline by roughly 1.5 percentage points after discontinuations. These reduced recoveries are measured relative to the vehicles' already lower post-discontinuation prices. These findings provide clear evidence that discontinued vehicles have reduced economic durability.

Our empirical tests hold fixed the model-vintage year of the vehicle (and include corporate parent-transaction year fixed effects), so we effectively compare the same model-vintage year vehicle before and after a discontinuation announcement, while controlling for changes at the corporate parent. While it is not a formal prediction of our stylized model, we further find that discontinued autos are financed with shorter maturity debt, which supports the contention that they have reduced durability.

Discontinuation is a deliberate choice of the manufacturer, but it is not under the direct control of other auto market participants. Buyers, sellers, and third-party financiers likely assign some

all components and it is especially problematic for external components (e.g., driver's side panels), which are most likely to be damaged in a collision. Moreover, even if third-party suppliers provide these non-interchangeable components, they will generally be more expensive due to their specialized nature.

[2]For instance, a *Chicago Tribune*, January 22, 2001 article on the announcement of the discontinuation of Oldsmobile notes "There is no question they're going to take a serious hit in resale value. Anyone who buys an Oldsmobile has to understand that unless they keep it until it's dead, it's not going to be worth much."

probability to a possible future model discontinuation, but its actual occurrence (i.e., with certainty) must represent adverse news. Moreover, we find no evidence of increasing anticipation before the announcement; there is no observable pre-trend in vehicle values, down payment, or LTV before discontinuation. For used auto buyers, sellers, and lenders, discontinuations appear to cause an unanticipated negative shock to economic durability.

We assess the relative importance of IBL for high- and low-income borrowers by tracing the effects of discontinuation-driven durability shocks on down payments, LTVs, and payment-to-income (PTI) ratios. First, we show that down payments are approximately $88 higher after discontinuations (a 9% increase relative to the mean). A post-discontinuation increase in down payments only occurs in the theory if future income is sufficiently pledgeable. Low-income consumers are forced to purchase the asset with a larger down payment, as their low future income does not allow them to borrow a large amount today. If income is not pledgeable to a meaningful degree, then the lower price of a less durable asset should lead it to be purchased with a lower down payment, which we do not observe.

Second, we show that discontinuation causes an increase of two percentage points in LTV ratios. This is a result that emerges in the model only if low-income borrowers make greater use of IBL. If high-income borrowers rely more heavily on IBL (or if only ABL lending is available), by contrast, the lower liquidation values produced by a discontinuation should lead to lower LTV ratios, which we do not find.

The model also predicts that if low-income borrowers are more reliant on IBL, then discontinued vehicles will be financed at lower PTI ratios, and we find that to be true as well. The uniform implication of the down payment, LTV, and PTI results is that in the U.S. auto loan market income is highly pledgeable and low-income borrowers are relatively more dependent on IBL.

We make use of data on lender recoveries from vehicle repossessions to distinguish the various mechanisms that link discontinuation to the degradation of the collateral value. Specifically, discontinued autos may physically degrade more quickly, and they may also attract buyers who do not have the financial resources to maintain their cars. The average proceeds from the sales of repossessed vehicles are $3,490. We show that borrowers who purchased vehicles after discontinuation have physical collateral recoveries in the event of default that are \$368 lower than those for control vehicles. By contrast, borrowers who purchased vehicles that were subsequently discontinued and who defaulted after discontinuation have collateral recoveries that are \$164 lower than for control cars. The latter result shows that, independent of borrower selection, discontinuation leads to worse recoveries. The difference in recoveries between these two classes of borrowers who both defaulted on loans held against discontinued cars is evidence in support of the argument that depreciation is to some extent borrower-dependent.

In the model incorporating IBL, lenders partially support their debt with a claim on the borrower's future income. In the event of default, do auto lenders actually make personal recoveries aside from the proceeds from vehicle repossession as this model predicts? We find that they do. For our sample of defaulted loans, we show that the average cash recovery from the borrower is \$1,207. This indicates that in default physical assets and personal borrower resources supply 74% and 26%, respectively, of the total recovery proceeds.

We offer an additional test of the claim that low-income borrowers make relatively greater use of IBL by analyzing personal recoveries from borrowers who purchased discontinued autos and later defaulted. We find that these personal recoveries relative to the defaulted loan balance are 1.9% higher than those arising from non-discontinued cars. Discontinued cars are less expensive and are acquired by lower-income borrowers, and yet we find that their purchasers, in the event of default, supply relatively larger personal recoveries. This perhaps counterintuitive finding is rationalized by the model. The lower-income borrowers who acquire less durable assets rely more heavily on IBL; given the low collateral value of these vehicles, if default occurs lenders seek personal recoveries.

It is clear that a key value of collateral lies in its providing an avenue for the lender to recoup potential losses after default. This theme has been explored in an influential theoretical literature (Bernanke and Gertler, 1989; Hart and Moore, 1994, 1998; Rampini and Viswanathan, 2010, 2013; Rampini, 2019; Demarzo, 2019) and has been extensively validated in empirical tests (Benmelech et al., 2005; Benmelech, 2009; Gan, 2007; Chaney et al., 2012; Cerqueiro et al., 2016; Jahan, 2020; Li and Tsou, 2020; Ioannidou et al., 2022). The IBL-specific component of lending, by contrast, is tied to the profit or income generated by the borrower (Dewatripont and Tirole, 1994;

Holmstrom and Tirole, 1997).

In the corporate setting, large and profitable borrowing firms make extensive use of unsecured lending (sometimes described as cash flow-based lending), while small and less profitable lending firms depend almost exclusively on asset-based lending supported by specific collateral (Leeth and Scott, 1989; John et al., 2003; Jimenez et al., 2006; Lian and Ma, 2021; Ma et al., 2022). That is, resource-constrained firms are more likely to use secured borrowing. By contrast, we show in the consumer auto loan market that IBL, an unsecured form of lending, is especially important for low-income borrowers. These divergent findings may arise from the fact that in the corporate market firms mainly choose between secured and unsecured business financing; the owner's personal capacity for IBL is generally of too small scale to support a firm's borrowing. Constrained firms make use of secured business borrowing, despite its costs, because it gives them access to more financing than unsecured business lending (Rampini and Viswanathan, 2020). In the consumer market, however, borrowers have the option of using IBL that is large enough to support their purchases. We find that low-income borrowers make particular use of this type of unsecured borrowing.

As described above, our empirical findings are best explained by a model in which high-income borrowers make greater use of ABL while low-income borrowers depend to a greater degree on IBL. A shift in financing markets that promotes ABL and disfavors IBL is therefore likely to offer disproportionate benefits to wealthy consumers. In the post-financial crisis period, there has been a dramatic expansion in the securitization of collateralized assets such as equipment relative to the securitization of unsecured debt such as credit card receivables and student loans. Our analysis suggests that this change in securitization markets should facilitate auto lending especially for high-income borrowers, and we indeed observe that wealthier borrowers have come to account for an increasing proportion of car loan financing.

Access to auto financing is particularly valuable in the U.S., where vehicle ownership is often critical for employment opportunities and mobility (Gurley and Bruce, 2005; Baum, 2009; Gautier and Zenou, 2010; Moody et al., 2021). Recent empirical evidence from Brazil corroborates the finding that vehicular access increases formal employment rates and salaries (Doornik et al., 2021).

Ensuring the ability of low-income consumers to borrow to purchase cars is therefore important for a broad set of policy goals.

Our results indicate that innovations that reduce the cost of monitoring borrower incomes (e.g., automated data links to borrower bank accounts) will likely promote the provision of financing via IBL to lower-income auto purchasers. Our findings also make clear that, in periods in which auto asset values rise more quickly than incomes, vehicle lending to constrained borrowers is likely to decline disproportionately. These points may be helpful in providing guidance to ensure that credit markets serve, to the maximum extent possible, to protect the relative financial access of economically disadvantaged borrowers.

1. Theoretical Framework

To illustrate the effects of a durability shock on the consumer financing of asset purchases, we provide a simple model of financing. In this section we outline the model and describe the main results. The technical details are supplied in the Appendix.

We assume that there are two types of consumers with either high or low income. Consumers can purchase either more durable or less durable assets from sellers (i.e., car dealerships) who charge a markup on sales. Both types of assets have a current period price and a residual value next period. Our central interest is in *economic durability*: we define this term to mean that assets with higher economic durability have both slower rates of price depreciation over time and higher prices today. Formally, we have:

Definition 1.

a) More durable assets have a higher ratio of residual value to current period price than less durable assets.

b) More durable assets have a higher price than less durable assets in the current period.

Differences across assets in economic durability may arise from variation in either physical durability or rates of intangible quality degradation.

Lenders provide financing at competitive rates. Consumers prefer current over delayed consumption and thus seek to maximize their leverage. Borrowers can access financing by pledging both the residual value of the asset next period as well as their future income. We refer to the former as asset-based lending (ABL) and the latter as income-based lending (IBL). ABL and IBL are both subject to limited pledgeability constraints which govern the degree to which lenders will provide financing for the given type of lending. For ABL, lenders may be able to seize the collateral at some cost. For IBL, mechanisms for securing the partial pledgeability of future income could include wage garnishment or bankruptcy repayment plans (Brown and Jansen, 2020).

We focus on the interesting region of the parameter space by assuming that high-income consumers can afford the more durable good if they borrow to their maximum feasible limit but that low-income consumers can only afford the less durable asset.[3] We further presume that the more durable asset is more attractive than the less durable asset to unconstrained borrowers. This generates the following result.

Result 1:

In equilibrium high-income borrowers purchase the more durable good while low-income borrowers purchase the less durable good.

Result 1 follows immediately from the assumed attractiveness of the more durable good and the constraints faced by low-income borrowers. We next consider the implications of the model for the contrasting financing patterns of high- and low-income borrowers.

Result 2:

a) If income is sufficiently pledgeable, then the down payment is higher for low-income borrowers purchasing the less durable asset than it is for high-income borrowers purchasing the more durable asset.

b) Otherwise, the down payment is lower for low-income borrowers.

Result 3:

a) If low-income borrowers rely relatively more on IBL than high-income borrowers, then the LTV ratio is higher for low-income borrowers purchasing the less durable asset than it is for high-

[3]Adams et al. (2009) find that down payments relative to income are often a constraint for vehicle purchases.

income borrowers purchasing the more durable asset.

b) Otherwise, the LTV ratio is lower for low-income borrowers.

Results 2b and 3b echo the intuitions from Rampini (2019) and Hart and Moore (1994) in which IBL is not considered. Result 2b follows from the fact that the higher price of the more durable asset is not offset one-for-one with more debt due to limited asset pledgeability and relatively low income pledgeability, which leads to higher down payments for the more durable good. Result 3b is driven by the feature that the more durable asset purchased by high-income borrowers offers a more pledgeable security; thus, the component of the LTV ratio due solely to asset-backed lending is therefore higher for high-income borrowers. If high-income borrowers also rely more heavily on IBL than low-income borrowers, then the IBL component of the LTV will also be higher for high-income borrowers.

Results 2a and 3a emerge only if IBL is sufficiently important and low-income borrowers rely relatively more on this type of borrowing. The intuition for Result 2a is that income must be sufficiently pledgeable for high-income borrowers to reduce their down payments by offering a large future income-based payment. Both high- and low-income borrowers pledge their future incomes as security for income-based lending, but low-income borrowers have less to pledge. As a result, as long as the difference in income between the two types of borrowers is sufficiently large relative to the the pledgeability of income, then low-income borrowers receive smaller income-based loans and therefore must supply a larger down payment to purchase the asset.

Under these assumptions less durable assets purchased by low-income borrowers thus have two features: they are purchased with less debt in dollar terms and they have lower residual values. A comparison of the LTV ratios of more durable and less durable assets therefore depends on the relative strength of these two effects. If low-income borrowers rely relatively more on IBL than high-income borrowers, then a greater proportion of the low-income consumer borrowing will depend on their future income rather than on the residual value of the asset. As a result, low-income borrowers will maintain a high level of debt (largely supported by IBL) relative to the low collateral value of their less durable assets. This yields Result 3a.

Contrasting Result 2a with Result 2b shows that higher down payments for low-income borrowers can only occur when income is sufficiently pledgeable. Moreover, it is clear from Results 3a and 3b that higher LTVs for the less durable good purchased by low-income borrowers require that those borrowers make relative heavier use of IBL.[4]

The model also has implications for borrowers' payment-to-income (PTI) ratios.

Result 4:

a) If low-income borrowers rely relatively more on IBL than high-income borrowers, then the PTI ratio is lower for low-income borrowers purchasing the less durable asset than it is for high-income borrowers purchasing the more durable asset.

b) Otherwise, the PTI ratio is higher for low-income borrowers.

Result 4a arises from the fact that the promised payment for the less durable good depends at least in part on its future residual value. If this future residual value for the less durable asset is very low, which is the case when the low-income borrower is heavily reliant on IBL, then the future payment must also be low.

There are parameters that simultaneously satisfy the conditions of Results 2a, 3a and 4a, as well as the other model assumptions. Thus the following implications arise from the model.

Model Implications. If

a) the down payment is higher for the less durable asset,

b) the LTV ratio is higher for the less durable asset,

and

c) the PTI ratio is lower for the less durable asset

then

i) Income must be sufficiently pledgeable

and

ii) Low-income borrowers must rely relatively more heavily than high-income borrowers on IBL.

Figure 1 presents a graphical illustration of the results. There are four regions describing the down payment, LTV, and PTI for the less durable asset purchased by the low-income consumer

[4]If parameters are chosen such that the high- and low-income borrowers both purchase the same asset, unlike in our main model, then low-income borrowers will have higher down payments and lower LTVs, as they can borrow less against their future income.

relative to the more durable asset purchased by the high-income consumer. As income pledgeability increases, IBL becomes a relatively larger portion of financing to purchase the asset. As the relative economic durability of the less durable asset decreases, IBL becomes relatively more important for the low-income borrower; when the residual value of the less durable asset is low, the low-income purchaser of that asset has little ability to rely on ABL. When income pledgeability is relatively high and relative economic durability of the less durable asset is low, which occurs in the light blue region (I), the LTV and down payment are higher for the less durable asset, and the PTI is lower. When income pledgeability is relatively low (i.e., below the dark red line), the lower price of less durable assets combined with the dearth of IBL for high-income borrowers leads to lower down payments for the less durable asset, as depicted in the purple region (IV).

If relative economic durability of the less durable asset is above a certain level, then low-income consumers rely relatively more on ABL and as a result their LTV is lower and their PTI is higher, as described in the dark blue (II) and orange regions (III).

In an extension of our base model, we consider the possibility of borrower-dependent depreciation. For example, low-income borrowers may be forced to forgo periodic maintenance of the asset, which could result in more rapid depreciation. In our base model, low-income borrowers purchase less durable goods with lower liquidation values. Borrower-dependent depreciation that is more severe for low-income consumers exacerbates this effect and leads to liquidation values for these buyers' assets that are even more reduced. As a consequence, the results from the base model hold in this extension as well.

Result 5:

If low-income borrowers experience a higher rate of depreciation for any given asset than high-income borrowers, then Results 1-4 and the Model Implications continue to hold.

2. Data

To explore the role of asset durability on consumer financing, we make use of two data sets. The first data set, supplied by Black Book, provides panel information across 746 vehicle make-models on wholesale values from car auctions of used vehicles.[5] In total, this represents 5,085 make-model-year observations spanning 2001 to 2020 model years.[6] The wholesale values that we use in our analysis cover the period from May 2001 to October 2020 and we compute annual wholesale values by averaging across monthly observations. We use these average wholesale values to calculate year-over-year (YOY) depreciation rates, which we define as the difference between this year's wholesale value and last year's wholesale value, with the difference scaled by the wholesale value last year. Summary statistics are reported in Table 1, Panel A.

The second data set, the loan data, describes loan terms offered from a large independent automotive indirect-finance company.[7] The data include all loans that were purchased by the firm in 44 states between the 1992 and 2021. In total, we observe key features of 291,493 loans that were originated at 3,929 dealerships located in 1,860 U.S. ZIP codes as described in Table 1, Panel B.[8]

The breadth and detail of our loan data distinguish our study from previous work. More specifically, we observe loan characteristics (e.g., purchase price and down payment) that are typically unavailable in aggregate data. For example, Experian Autocount data do not measure down payments and sale prices, limiting the construction of collateral measures.

Table 1, Panel B, presents summary statistics from the loan data of the buyer, loan, and vehicle characteristics that were observable to the dealer at the time of origination for all loans in our sample where we observe complete origination data. In our sample, the median vehicle is two years old and has approximately 38,000 miles when sold. The median vehicle has a value of $13,025, and the median down payment is $800 (roughly 6% of the vehicle's value). The median loan in our sample has a term of 72 months (6-years) and an APR of approximately 19.5%. The high APR reflects the fact that the borrowers in the sample are subprime—the median reported

[5] The wholesale values reflect prices paid by dealerships for the purchase of vehicles, and are adjusted for mileage, condition history, and region. The Black Book data cover more than 95% of all auction sales.

[6] In the Black Book data we exclude four luxury brands (Maserati, Porsche, Tesla, and Hummer) because these brands are likely to have different depreciation dynamics and are not representative of our loan data.

[7] This firm is not one of the captive auto lenders studied by Benmelech et al. (2017) and Benetton et al. (2021).

[8] The raw data include approximately 343,000 loans. We exclude loans with incomplete origination data and vehicles older than 7-years. The latter exclusion is because we have limited data on vehicles older than 7-years in our sample (approximately 0.25% of the total sample).

credit score is approximately 530, with roughly 30% of borrowers having a reported bankruptcy (chapter 7 or 13) within seven years of loan origination.

3. Discontinuations

3.1. Background

To causally identify the impact of economic durability on financing, we require a source of exogenous variation in asset economic durability. Moreover, to separate any general effect of durability from other technological shocks in the time series (e.g., financial engineering or digital processing of applications), we require a shock that affects only some vehicles but that still allows for controls for vehicle age, manufacturer, model, and the year the vehicle was sold. Ideally, we would randomly assign similar vehicles different economic durability. While this may not be feasible, we can take advantage of shocks to existing vehicles that affect their current and future resale values. Specifically, we utilize the discontinuation of makes and models of vehicles as a source of exogenous variation in vehicle economic durability in our data.

Importantly, this shock does not affect the current quality of a used car because no component of the car changes. In this sense the shock to quality is only forward looking, although it may, of course, be reflected in current prices. Prior to discontinuation, the car is made is in the same factories with the same materials. Moreover, by comparing car prices prior to discontinuation to the same model and year of car post-discontinuation, we can hold constant the car quality and use vehicles that were not shocked to control for the but-for depreciation curve and other time-varying attributes of the market.

One concern with this shock is that the decision to discontinue a make and model of car by the car manufacturer is an endogenous decision and there are many reasons a manufacturer may choose to do so. For instance, a car manufacturer may choose to cut less profitable models during times of financial distress. However, in our specifications we can directly control for the parent car company and thus can compare cars of similar quality within the same car manufacturing family. Thus, any effect on durability due to potential future bankruptcy, as noted in Titman (1984) and shown to be empirically important in Titman and Wessels (1988) and Hortaçsu et al. (2013) among others, should affect all cars made by that manufacture. Additionally, in several cases the discontinuation happened when the auto manufacturer was not under financial distress. Moreover, by comparing pre-trends of the vehicles, we can plausibly detect any movements in the resale or depreciation value of the vehicles prior to the shock.

3.2. Discontinuation Shocks

In the last twenty-five years 825 car models have been discontinued. Among the 825 discontinued models, we identify 208 instances in which the manufacturer decides to maintain the make of the car (e.g., Chevrolet) but discontinues a specific model (e.g., Chevrolet Monte Carlo), and the model appears in our loan data.[9] We supplement these model discontinuations with eight discontinuations of major US car brands (i.e., makes) during our sample period. A list of discontinued models, discontinued makes and discontinuation years is provided in the Appendix in Table B.3 and Table B.4.

3.3. Empirical Method

We use a difference-in-difference (DiD) approach to test the effect of our shock to depreciation. Specifically, for a transaction i, of model j of vintage v, with parent p and dealer d, during period t, we estimate the following regression:

$$Y_{i,j,d,t,v,p} = \tau_t + \iota_{j,v} + \xi_d + \pi_{p,t} + \beta X_{i,j,d} + \phi_{j,t}\text{Treated}_{j,t} + \epsilon_{i,j,d,t}, \tag{1}$$

where Y is an outcome such as vehicle price or financing term, τ is a transaction year fixed effect, ι is a car model x vintage year fixed effect, ξ is a dealer fixed effect, X are a series of vehicle, borrower, and dealer controls, and Treated is an indicator if the make of model j has been discontinued prior to time t. Thus, in the cross-section we are comparing cars within the same period, absorbing any

[9]More than half of the discontinued models that are discontinued include low volume production vehicles such as the Aston Martin Vantage GT and the Ferrari 248.

non-time varying attributes related to the specific model, and dealer, as well as any linear effects of vehicle age. In addition, we also include fixed effects for the interactions of the car make's parent company x transaction year fixed effects ($\pi_{p,t}$). Thus, we are also absorbing any effects related to the financial condition of the parent company at the time of the transaction. Importantly, this isolates general effects that would apply to all makes of a given parent company (e.g., GM during the 2008-2009 Global Financial Crisis). In all specifications we cluster by make.[10]

4. Results

4.1. Discontinuation Shock and Economic Durability

We propose to use the model and brand discontinuations described in Section 3 as a shock to vehicle economic durability. Parts availability and servicing expertise for discontinued vehicles are likely to degrade more quickly than for other vehicles. There may also be a loss of prestige that leads to lower current prices. From the perspective of the theoretical framework described in Section 1, this suggests that discontinuation may be viewed as a shock that reduces the economic durability of a car.

We begin by utilizing the Black Book data to empirically assess the impact of discontinuation on economic durability. Definition 1a in Section 1 requires that more durable assets have a higher ratio of residual value to current period price (i.e., lower YOY depreciation), so if discontinuation reduces durability, then it should increase the rate of depreciation. We test this implication by estimating equation (1) and regressing a vehicle's YOY depreciation on a post-discontinuation indicator, model-vintage year fixed effects, and corporate parent-contract year fixed effects. Our

[10] Several recent papers raise concerns of differential treatment timing in difference-in-difference regressions and raise the spectre of resulting bias when using higher dimensional fixed-effects if there is expected treatment effect heterogeneity (Callaway and Sant'Anna, 2021; Baker et al., 2022). We note several features of our analysis that should alleviate such concerns. First, in the loan sample we drop all observations where the vehicle age exceeds seven years. This reduces the potential for long-run effects to drive the results and for previously discontinued vehicles to act as future controls. Second, we note that 83% of our observations are never treated, reducing the likelihood of negative weights (Goodman-Bacon, 2021). Finally, we repeat our baseline specifications using the stacked regression approach of Gormley and Matsa (2011) and Cengiz et al. (2019), and find similar results.

use of model-vintage year fixed effects allows us to contrast vehicles of the exact same model and vintage year before and after discontinuation. Corporate parent-contract year fixed effects remove any impacts that influenced the corporate parent. It is plausible that corporations that discontinue a make or model may differ from those that do not. For example, it could be that corporate parents that discontinue a make or model may have weaker balance sheets and may therefore be less capable of guaranteeing future warranties. The corporate parent-contract year fixed effects control for any impacts of this kind. Taken together, this complement of fixed effects isolates the impact of discontinuation itself on the specific model that will no longer be manufactured.

We find, as shown in the first column of Table 2, that discontinued vehicles depreciate by an additional -1.2% (t-statistic=-2.60) per year. This is a meaningful effect relative to the average depreciation rate of -15%. This finding of more severe depreciation after discontinuation is consistent with the claim that discontinuation reduces economic durability. In the second column of Table 2 we show that vehicles experience sustained rates of elevated annual depreciation after discontinuation, ranging from -0.8% (t-statistic=-2.46) in the first year after discontinuation to -3.3% (t-statistic=-6.17) in the sixth post-discontinuation year. These results are illustrated graphically in Figure 2.

The initial increase in depreciation in the first year after discontinuation likely reflects both the impaired physical durability of discontinued vehicles and the stigma associated with these cars. The fact that the rate of depreciation is greater in subsequent years, however, probably largely arises from a decrease in physical durability, as it seems unlikely that the loss of prestige for discontinued cars would increase over time as a fraction of overall value.

The second key feature of less durable assets, which is highlighted in Definition 1b in Section 1, is that they have a lower prices. We show in the third column of Table 2 that discontinuation leads to a $1068.2 drop ($t$-statistic=-2.50) in vehicle wholesale values. This is a meaningful decrease compared to the average wholesale value of $13547. As displayed in the fourth column of Table 2, the price effect is substantial in the first year after discontinuation (coefficient= -1055.1 and t-statistic=-3.00) and is larger in subsequent years.[11] Table 2 makes clear that discontinued vehicles

[11] We present the event study plot for the wholesale value in Appendix Figure B.2.

are less economically durable, exhibiting both heightened rates of annual depreciation and lower prices.

As a second set of tests, we examine the impact of discontinuation on the vehicles in our loan data. These data describe sales of individual vehicles, so they may be utilized to analyze prices, but they are not in the form of a panel that allows for the calculation of annual depreciation. We regress the vehicle wholesale value on a post-discontinuation indicator, model-vintage year fixed effects, dealer fixed effects and corporate parent-contract year fixed effects, which we refer to as the standard set of fixed effects. We find, as shown in the first column of Table 3, that discontinued vehicles experience a change in wholesale value of -\$297.6 (t-statistic=-2.58). The negative sign of this effect is consistent with the results in Table 2. The magnitude of the drop is smaller than for the vehicles in the Black Book sample, which may arise from the fact that the loan data are generated from sales to subprime borrowers, whereas the Black Book data describe a broad cross-section of vehicles.[12]

Including controls for borrower income and credit score, indicators for prior borrower chapter 7 or chapter 13 bankruptcy filings and an indicator for borrower homeowner status leaves the qualitative finding unchanged, as shown in the second column of Table 3. Including a control for vehicle mileage and dealer profit yields the result that discontinuation reduces wholesale value by \$277.88 (t-statistic=-2.57).

As an additional measure of vehicle value we consider the scaled price, which is defined as the vehicle wholesale value divided by the average wholesale value of the given vehicle model and vintage when new. We show in the fourth column of Table 3 that the scaled price is 3.89 percentage points lower (t-statistic=-4.59) post-discontinuation. The results from the specifications including borrower, vehicle mileage and dealer profit controls in the scaled price regressions support the conclusion that discontinuation reduces vehicle value, as shown in the fifth and sixth column of Table 3.

As an additional test for whether discontinuation can be viewed a negative durability shock, we study the recovery percent of a vehicle, which we define to be the value the lender receives from the

[12]The autos in the Black Book data also have higher wholesale values when new than the vehicles in the loan data.

vehicle's liquidation after default divided by the vehicle's wholesale value at origination. We regress the recovery percent on the post-discontinuation dummy and the standard fixed effects. We note here for clarity that we assign the post-discontinuation indicator to a vehicle if it is *purchased* after discontinuation. As we showed in Tables 2 and 3, these vehicles have lower current period prices when purchased. In the present test we explore whether their future recovery values are lower, as a fraction of their already reduced prices, relative to other vehicles.

We find, as shown in the first column of Table 4, that the recovery percent is 1.73 percentage points lower (t-statistic=-3.33) for post-discontinuation vehicles. This drop may be compared to the average recovery ratio of 28 percent. In the second column of Table 4, we show that including borrower, vehicle mileage, and dealer profit controls as well as a control for the time to default yields a coefficient of -2.27 percentage points (t-statistic=-4.78) on post-discontinuation. Including an additional fixed effect for the model-year of default as well as controlling for the recovery type results in an estimated coefficient of -1.54 percentage points (t-statistic=-2.85), as shown in the third column of Table 4. These results support the general conclusion that discontinued vehicles have lower residual values, even when viewing those residual values as a fraction of their lower prices at origination.

Tables 2, 3 and 4 make clear that the discontinuation shock reduces economic durability as described in Definition 1. Discontinued vehicles have higher rates of depreciation, lower prices and lower residual values, and we consequently view them as less durable assets for the purpose of testing the theoretical predictions outlined in Section 1.

4.2. Durability and Consumer Income

Result 1 in the theoretical framework presented in Section 1 is that high-income borrowers will purchase more durable assets. The basic intuition is that more economically durable assets are attractive but expensive. We test this prediction by regressing an indicator for whether a borrower had a bottom quartile income relative to all borrowers in that year on the post-discontinuation dummy and the standard fixed effects. We find, as shown in the first column of Table 5, that discontinuation increases the probability that the purchaser is in the bottom income quartile by

3.45 percentage points (t-statistic=2.93). This finding supports Result 1: low-income borrowers are more likely to buy the less durable discontinued vehicles. Including controls yields a similar conclusion, as shown in the second column of Table 5. A regression of the log of borrower income on discontinuation yields a coefficient of -0.01 (t-statistic=-2.03), as displayed in the third column of Table 5. This result is robust to controlling for the vehicle mileage and dealer profits, and also emerges in specifications utilizing Poisson regressions as suggested by Silva and Tenreyro (2006) and Cohn et al. (2022), as shown in columns four through six of Table 5. Discontinued vehicles are purchased by lower-income borrowers, and the the effect is especially pronounced for borrowers in the bottom income quartile.

4.3. Durability and Loan Maturity

The model we consider in our theoretical framework involves one period loan repayments, so it does not generate formal predictions for the impact of durability on loan maturity. It is intuitive, however, that less durable assets will be financed with shorter-term asset-backed debt, and this implication arises, for example, in the model of Hart and Moore (1994). Hart and Moore (1994) also argue that human capital cannot support long-term debt as it belongs only to its owner and may be withdrawn from use at any time. A reduction in durability that leads to greater use of income-based financing should thus lead to shorter-term financing. Both asset-backed and income-based models of financing therefore suggest that a decrease in asset durability will result in shorter-maturity debt.

We test this hypothesis by regressing the observed maturity in months of the auto loan on the post-discontinuation dummy and the standard fixed effects. We find that discontinuation reduces the maturity of the loan (coefficient=-0.82 and t-statistic=-5.64), as displayed in the first column of Table 6. The reduction of 0.82 months in loan maturity after discontinuation is a meaningful effect, though perhaps not very large compared to the mean loan maturity of 67.59 months. Overall, however, there is little observed variation in loan maturities (the interquartile range is 66 to 72 months), so it is notable that we find an effect of reasonable magnitude. As in Argyle et al. (2021), we find that cars with shorter expected lives receive loans with shorter maturities. Including borrower, vehicle, and dealer profit controls has little impact on the estimated coefficient, as we show in the second and third columns of Table 6.

4.4. Durability and Down Payments

The results described above in Section 4.1 serve to validate the use of discontinuation as a shock to economic durability. The results in Sections 4.2-4.3 support the implications of theory for the impact of a reduction in durability on borrower income and loan maturity.

The model offers conflicting predictions for the impact of economic durability on the dollar value of the borrower's down payment (i.e., the cash amount paid by the borrower on the transaction date). When income pledgeability is low, more durable assets require larger down payments (Result 2b); while when income pledgeability is sufficiently high, borrowers purchase less durable assets with larger down payments (Result 2a).

We regress the down payment on the post-discontinuation indicator and the standard fixed effects. We find that discontinuation leads to larger down payments, as displayed in the first column of Table 7. Consistent with the implication in the model when income is sufficiently pledgeable, borrowers supply an additional \$85.3 (t-statistic=3.76) in down payments when purchasing less durable discontinued vehicles. As shown in Figure 3, down payments climb significantly after discontinuation and do not exhibit any apparent pre-trend.

This down payment result is particularly surprising from the perspective of a model with only asset-based collateral, i.e., if income was not pledgeable. We showed above in Table 3 that discontinued vehicles are less expensive. This fact, along with the limited pledgeability of collateral emphasized in asset-backed models of lending, should lead discontinued autos to require lower down payments. Moreover, we demonstrate in Table 5 that these vehicles are purchased by lower-income borrowers who presumably have less cash in hand for a down payment. Despite these two compelling intuitions for a prediction that there will be lower down payments for less durable assets, we find the opposite. This finding in the context of the model shows that income-based lending is a relatively important feature of auto lending. Given that low-income consumers have smaller future incomes against which to borrow, the low-income purchasers of less durable assets need to provide larger down payments to close the transactions.[13]

The positive impact of discontinuation on down payments continues to hold when controlling for borrower and vehicle characteristics, as detailed in the second column of Table 7. We show in the third column of Table 7 that in the cross-section more expensive vehicles with elevated book values generally require higher down payments. There are, however, many unobserved differences between vehicles of different prices. Our result that discontinuation shocks lead to higher down payments on vehicles of specific model-vintage years is somewhat stronger when controlling for this vehicle book value effect, as is displayed in the third column.

The higher down payments for less durable assets that we find indicate that the empirically relevant regions of Figure 1 are restricted to region I (light blue) or region II (dark blue). Only for the high levels of income pledgeability that hold in those regions will low-income borrowers make the higher down payments that we observe. Regions III and IV are incompatible with the down payment results in Table 7.

4.5. Durability and LTV ratios

In this section, we consider the implications of the model for the LTV ratio. Specifically, in the theory when IBL is relatively unimportant for low-income borrowers, LTV increases with durability (Result 3b), but when IBL is relatively important for low-income borrowers, LTV decreases with durability (Result 3a).

We define the LTV to be the ratio of the loan balance to the wholesale value of the auto at the time of origination. We regress LTV on the post-discontinuation indicator and the standard fixed effects, and we find a positive and significant coefficient of 0.02 (t-statistic=3.63), as displayed in the first column of Table 8. This result shows that a discontinuation shock reducing vehicle durability leads to higher LTV ratios, which, as we describe in Section 1, arises only in the model when low-income borrowers depend heavily on IBL. Figure 4 shows that LTV ratios exhibit no

[13] This result aligns with the findings of Adams et al. (2009) and Einav et al. (2012), who show that borrowers that are riskier in observable dimensions make larger down payments, though they do not find an independent effect of income or mileage. Our focus on a shock to durability and our analysis of the ABL-IBL trade-off is not shared by Adams et al. (2009) and Einav et al. (2012).

pre-trend before discontinuations and are higher afterwards

It is a general and robust feature of models of asset-backed financing that LTV increases with durability (Hart and Moore, 1994). When the asset constitutes the entire collateral, as in a model without IBL, more durable assets with higher liquidation values support larger loans relative to current values. We also find this implication in our model when IBL is relatively less important for low-income borrowers (these are regions II and III in Figure 1). Our finding to the contrary indicates that in the auto loan market, income-based lending must play a meaningful role and that it is especially important for low-income borrowers. Our model describes a setting in which borrowers can rely on their future income to purchase assets. Low-income borrowers, in particular, use their future income to purchase less durable assets. If the price of the less durable asset is relatively low, then low income borrowers will purchase it with a relatively high debt ratio, as the debt is secured by their incomes, not just by the physical collateral. This mechanism in the model is consistent with the finding that LTV *increases* after a decline in durability.

Including borrower controls has little impact on the estimated effect of the discontinuation shock on LTV, as shown in the second column of Table 8. In the third column of Table 8 we display the similar results when including the full set of vehicle and borrower controls (coefficient=0.02 and t-statistic=6.74). The general conclusion is unchanged: less durable autos are financed with higher LTV ratios, which emerges as a potential outcome in the model only when low-income borrowers are relatively more dependent on IBL.[14]

We have thus shown in Tables 7 and 8 that less durable assets have both higher down payments and higher LTVs than more durable assets. The only region in Figure 1 for which both these outcomes hold true is region I. The data thus indicate that in the U.S. auto loan market income is quite pledgeable and low-income borrowers rely relatively more heavily on IBL.[15]

[14]The post-discontinuation increase in LTV ratios does not reflect a shift in default risk; we find in unreported results that the latter does not change significantly with the discontinuation shock. We also note that the specifications with borrower characteristics employ a wide set of risk measures such as credit scores, income and bankruptcy indicators, and the inclusion of these controls has little impact on the estimated coefficient on post-discontinuation.

[15]In Figures B.3 and B.4 of the Appendix we present permutation tests of the results for year-over-year (YoY) depreciation, Scaled Price, Down Payment, and LTV (Tables 2, 3, and 8, respectively) based on Ganong and J́ager (2018). Using this test, find that our results are significant at the 5% level indicating

We further comment that the mean (and median) LTV for our auto borrowers is 129%.[16] In a model where income pledgeability was low (i.e., little IBL) this high level of debt would be unexpected, as lenders can only seek repayment from the asset value. LTVs of above 100% can be supported, however, when income is sufficiently pledgeable, as the borrower's future income is also used to meet the required debt payments. This is also consistent with market parameters lying in region I of Figure 1.[17]

4.6. Durability and Payment-to-Income Ratios

Result 4 of the model predicts that the payment-to-income ratio will be lower for less durable assets if low-income borrowers are more heavily dependent on IBL (as is the case in region I of Figure 1). This provides an additional model implication that we explore.

We test this prediction by regressing the log of the borrower's payment-to-income (PTI) ratio on the post-discontinuation variable and the standard fixed effects. We find a negative and significant effect of discontinuation on the log of PTI (coefficient=-0.02 and t-statistic=-2.51), as displayed in the first column of Table 9. PTI ratios of the purchasers of these vehicles drop by 2 percent after discontinuation is announced.

Including borrower income decile fixed effects has little impact on the estimated negative coefficient on discontinuation, though it does increase the precision of the estimate, as shown in the second column of Table 9. Introducing borrower and vehicle controls, either with or without borrower income decile fixed effects, also yields similar estimates, as described in columns three and four of Table 9. Using the PTI ratio rather than the log as the dependent variable yields similar directional results and significance but lower magnitudes, as displayed in columns five through eight

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that they are unlikely to be due to chance or mechanical effects.

[16]We further note that the mean LTV for prime auto borrowers (FICO score of 661 to 780) is 131%, while it exceeds 139% for subprime borrowers (Zabritski, 2019).

[17]At first glance it may seem surprising that discontinued vehicles have lower prices and higher down payments, yet carry higher LTV ratios. This can occur, however, when dealers charge markups and LTVs are calculated relative to the book values of the vehicles. For example, suppose a more durable asset sells for 150, has a book value of 135 and is financed with 145 in debt and a down payment of 5. Suppose the less durable asset sells for 130, has a book value of 115 and is financed with 124 in debt and a down payment of 6. In this case the less durable asset has a lower price, a higher down payment and a higher LTV ratio.

of Table 9. This is due to a wide distribution in PTI that may skew the results. Figure 5 shows that borrower PTI drops after discontinuation, with no visible pre-trend.

The full set of findings across down payments, LTVs and PTIs offers consistent support for the argument that income is pledgeable and that low-income borrowers rely more heavily on IBL, as described in region I of Figure 1.

4.7. Durability and Recovery in Default

In the discussion above we highlight the role of IBL. For IBL to be important, however, it must be that consumers are able to borrow against their future income and need not rely solely on the physical asset to serve as collateral. In this section we discuss the direct evidence on post-default lender collections. In particular, is it the case that lenders actually take recovery from the personal resources of borrowers?

We have data on the recovery proceeds from 76,638 defaulted loans where we observe both income and vehicle recoveries. For this sample, we find that the average proceeds from the sales of repossessed vehicles are \$3,490. The average cash recovery from the borrower is \$1,207. We thus find that in default, physical assets and personal borrower resources supply 74% and 26%, respectively, of the total recovery proceeds. These summary statistics show that in the auto loan market, a market in which vehicle collateral is generally deemed to serve a central role, borrower personal income pledges do perform a significant function.

4.8. Income-based Lending to Low-Income Consumers—Default Recoveries

As outlined in the model developed in Section 1, the results in Table 7 showing that a reduction in durability leads to larger down payments demonstrate that income-based lending is important in the auto financing market. The empirical findings on LTV and PTI in Tables 8 and 9 establish that low-income borrowers rely more heavily than high-income borrowers on IBL.

The default recovery data make possible an additional test of these implications. We show in Table 5 that discontinued vehicles tend to be purchased by low-income consumers. Given the results in Tables 7 to 9, the model's implications are that low-income borrowers rely relatively more on IBL. We should therefore expect to observe lower vehicle recoveries and higher personal income recoveries from the purchasers of discontinued vehicles who default.

In the model extension outlined in Section 1, we discuss the idea that different borrowers may experience varying levels of asset depreciation for the same vehicle. The recovery data enable us to examine this hypothesis, as we can contrast outcomes for borrowers who purchased vehicles that were later discontinued with outcomes for borrowers who purchased vehicles after the discontinuation announcement. Both types of borrowers experience the impact on their vehicles of a discontinuation, but the borrowers themselves differ in that only the first group of borrowers chose to purchase what were at the time non-discontinued cars. Any observed differences across the two borrower types in their recovery rates would therefore constitute evidence in favor of borrower-dependent depreciation. In order to ensure that the vehicles of these two borrower groups are comparable, for cars that are discontinued or eventually discontinued only autos purchased within 2 years of a discontinuation are included.

We begin by analyzing recovery rates for borrowers who purchased their vehicles after a discontinuation announcement. Consistent with our labeling in the previous tables, we describe these as *Post Discontinuation* transactions. We regress the value of the vehicle recovery on the post-discontinuation indicator, the standard fixed effects and additional fixed effects for the corporate parent-default year and the form of recovery. We find, as displayed in the first column of Table 10, that vehicles purchased post-discontinuation are worth \$261.8 less (t-statistic=-4.49) in repossession. These vehicles are less durable and therefore provide diminished physical recovery proceeds, as expected under the model. It may also be the case that the purchasers of the vehicles are less able to maintain them, resulting in even higher rates of depreciation.

As a point of contrast, we examine the vehicle recovery proceeds from cars purchased prior to discontinuation that experienced default after discontinuation. We label these transactions as *Purchase Before, Default After*.[18] In the second column of Table 10 we show that these vehicles have \$194.0 lower (t-statistic=-2.25) recoveries. The purchasers of these cars did not choose to buy

[18] Given our regression specification, model-default year fixed effects would fully absorb the *Purchase Before, Default After* indicator. We therefore employ in Table 10 parent company-default year fixed effects.

a discontinued auto: discontinuation was an ex post shock that they experienced.[19] The drop in vehicle recoveries we find for this group therefore constitutes evidence of higher post-discontinuation depreciation that affects the physical asset independent of the borrower type.

The coefficient on *Post Discontinuation* in this regression is -432.3 (t-statistic=-4.30). This coefficient is larger in magnitude than the coefficient on *Purchase Before, Default After*, with the difference statistically significant at the 5% level. The relatively lower recovery for borrowers who purchased their vehicles after discontinuation, compared to those who experienced discontinuation following purchase, is evidence in favor of borrower-dependent depreciation. This regression includes fixed effects for both model-vintage and parent-default year, so we are comparing outcomes for similar vehicles that defaulted at the same time and that had been discontinued at the time of default. The reduced recovery for post-discontinuation buyers suggests that, perhaps due to financial constraints, these consumers were unable to maintain the values of their vehicles in the same manner as those who purchased them before the discontinuation. Including borrower, vehicle mileage, dealer profit, and time to default controls has little impact on the estimated coefficients on *Purchase Before, Default After* and *Post Discontinuation*, as detailed in the third column of Table 10; both remain significant and statistically distinct from each other at the 5% level. Figure 6 provides a graphical depiction of vehicle recoveries for both borrowers who experienced a discontinuation after purchase and for those who purchased after discontinuation.[20]

A decrease in durability reduces not only the dollar amount recovered from the repossessed asset, but also the percentage of the loan balance recovered through liquidation. We find, as detailed in the fourth column of Table 10, that that the percentage of the loan balance recovered through liquidation of the vehicle is lower for vehicles purchased after discontinuation. In the fifth column of Table 10, we show that the effect of *Post Discontinuation* (coefficient=-2.94 and t-statistic=-5.39) is greater in magnitude than the impact of *Purchase Before, Default After* (coefficient=-1.36 and

[19] Our approach is similar to that of Karlan and Zinman (2009) and Jack et al. (2023) who make use of unexpected ex post variation to distinguish selection and treatment effects.

[20] Figure 6 is conditional on positive recoveries on the vehicle. In Figure B.5 in the Appendix we plot the complete set of recoveries and find similar results on the intensive margin. Both borrowers who experienced a discontinuation after purchase and those who purchased after discontinuation have a higher likelihood of zero recovery than control borrowers.

t-statistic=-2.14), and the difference is statistically significant at the 5% level. The results for the specification including the full set of controls, outlined in the sixth column of Table 10, are quite similar. These findings buttress the argument that asset depreciation varies with borrower type.

While it is perhaps unsurprising that vehicle recoveries are lower for discontinued vehicles, it is a novel implication of the model that personal income recoveries as a fraction of the loan balance should be higher for these cars, as they are purchased by low-income borrowers who rely more heavily on IBL.[21] We regress the dollar amount of personal post-default payments on the post-discontinuation indicator and the fixed effects described above. We find, as displayed in the first column of Table 11, that the dollar amount weakly increases (coefficient=110.4 and t-statistic=1.79) after discontinuation. A similar result holds in the specification with borrower, vehicle and dealer profit controls, as shown in the second column of Table 11. When including the gross default amount as a control, there is somewhat stronger evidence an increase in income recovery (coefficient=145.0 and t-statistic=2.32), as displayed in the third column of Table 11.

The ratio of the personal borrower payments to the defaulted loan balance also weakly increases after discontinuation (coefficient=1.70 and t-statistic=1.94), as we detail in the fourth column of Table 11. Including controls somewhat strengthens this conclusion (coefficient=1.89 and t-statistic=2.13); the results are displayed in the fifth column of the table.

Taken together, the results in Tables 10 and 11 provide support for the contention that low-income borrowers rely more heavily than high-income borrowers on their income as a source of collateral. It is notable that purchasers of discontinued vehicles make larger personal payments after default. These consumers have lower incomes and they buy less expensive vehicles. For both of these reasons, one might have expected them to be supply smaller personal recoveries relative to their loan balances in the event of a default, yet we find the opposite. The model supplies the intuition for our finding: purchasers of discontinued less durable vehicles must pledge their own income, rather than the quickly depreciating physical asset, in order to receive a loan. In the event

[21] The model does not have any implications for the income recoveries of *Purchase Before, Default After* borrowers. Given that the eventual discontinuation experienced by these borrowers was unexpected, their original loan terms should not depend to a greater extent on IBL. As a consequence, we focus in the income recovery analysis on borrowers who purchased their vehicles post-discontinuation, and we do not restrict attention, as we did in Table 10, to vehicles purchased within two years of a discontinuation.

of default, a lender therefore must have recourse to their income, as the physical collateral does not have much value.

5. Discussion

5.1. Secured and Unsecured Lending for Consumers and Firms

We find that low-income borrowers depend heavily on IBL, as demonstrated by the higher LTVs, lower PTIs, and higher personal recoveries on discontinued vehicles. That is, riskier consumers depend heavily on unsecured borrowing. This feature of consumer credit contrasts starkly with the financing pattern in the corporate market. Leeth and Scott (1989), John et al. (2003), Jimenez et al. (2006) and Lian and Ma (2021) all show that better-resourced firms make greater use of unsecured lending, while riskier and more constrained businesses are more likely to utilize collateral and secured lending. What explains this sharp divergence in the risk profiles of unsecured borrowers in the two markets? The analysis in Section 1 makes clear that IBL can only influence financing when income is sufficiently large. The personal income-derived payments in default of a consumer are significant in scale when compared to the purchase price of an automobile.

Firms, by contrast, may borrow on either business or personal accounts (Chava et al., 2022; Fonseca and Wang, 2022). On their business accounts, firms face a choice between secured and unsecured borrowing and constrained firms may make greater use of secured business debt, despite its costs, because it offers greater financing access (Rampini and Viswanathan, 2020). For most firms, the personal income-based borrowing of the owner can only cover a small fraction of their corporate financing needs. Unsecured IBL, therefore, is not a meaningful option for many constrained firms.

5.2. Trends in Consumer IBL

The dependence by low-income borrowers on IBL that we document suggests that recent changes in securitization markets have potentially broad implications for the relative auto credit access of poor consumers. Specifically, Figure 7 displays total annual securitization issuances for autos, equipment, student loans, and credit cards. As is clear from the figure, in the post-financial crisis period (i.e., since 2008) there has been a significant increase in the securitization of ABL such as equipment relative to IBL such as student loans and credit cards. One possible rationale for this shift is that it became apparent during the financial crisis that monitoring incentives were reduced for securitized debt (Keys et al., 2010), and such monitoring is likely more important for IBL than for ABL. A second candidate explanation is that post-crisis Basel III risk weightings of bank loans adjusted to favor collateralized assets (Degryse et al., 2021), which may have led to both reduced originations and decreased securitizations of IBL. Irrespective of the underlying cause, we argue that this change in securitization is important for auto financing, which, our study argues, is a composite of ABL and IBL.

In particular, a rise in ABL securitization relative to that of IBL is likely to facilitate the availability of the former type of financing at lower prices. Given the importance of the IBL component of auto debt to low-income borrowers, this suggests that an increasing fraction of vehicle lending will be directed to wealthier consumers. To explore the effects of changing market conditions, we examine the relationship between auto financing of consumers and the securitization of ABL relative to securitization of IBL. Specifically, each year we calculate the ratio of securitized equipment lending, which is almost entirely ABL, to the sum of equipment, credit card, and student loan lending, where the latter two are almost entirely IBL.[22] We then plot the relationship across the highest and lowest income quartiles since the onset of the financial crisis in Figure 8.[23] As the ratio of equipment to total securitization increases, borrowers in the highest income quartile experience an increase in auto financing, while borrowers in the lowest income quartile experience a decrease. Although this figure depicts an association rather than a causal connection, it is consistent with the argument that the importance to low-income borrowers of IBL, which has been relatively disfavored by securitization markets, may be acting to reduce their ability to purchase vehicles.

Our results establishing the importance of IBL for low-income borrowers also suggest that their relative access to credit will be improved by measures that increase the pledgeability of income. For example, the Bankruptcy Abuse Prevention and Consumer Protection Act of 2005 could be argued

[22]To avoid any mechanical relationship, we exclude securitized auto lending.
[23]We present the regression underlying this analysis in Appendix, Table B.5.

to facilitate borrowers' income-based lending. A measure with this kind of effect is likely to have a relatively more beneficial impact on lending to low-income consumers than changes in regulations that are argued to promote ABL, such as reductions in the cost of repossessing vehicles.

Vehicles play an important role in helping consumers access jobs and achieve mobility, and their prices have recently been increasing.[24] Restricted credit access for low-income borrowers arising from their reliance on IBL may narrow their prospects. Financially constrained car purchasers receive no federal auto financing assistance, despite the darkening credit conditions for these consumers and the crucial part cars play in creating opportunity. This contrasts with mortgage financing where the U.S. government devotes significant resources to facilitating access, largely for the benefit of less-wealthy citizens.

6. Conclusion

We study the roles of asset-backed lending (ABL) and income-based lending (IBL) in the $1.3 trillion U.S. automotive lending market. Using a simple theoretical framework, we show that tracing the effects of a reduction in asset economic durability on financing allows us to assess the overall importance of IBL and its relative usage by high- and low-income borrowers. Specifically, when income pledgeability is low (i.e., IBL plays a small role) and low-income borrowers rely relatively less on IBL, less durable assets have lower down payments and LTV ratios. By contrast, when income pledgeability is high and low-income borrowers rely relatively more on IBL, less durable assets have higher down payments and LTV ratios. In our empirical analysis, we show that model and make discontinuations generate a negative economic durability shock for used cars: post-discontinuation, holding fixed the model-vintage year, we observe that discontinued vehicles have higher rates of depreciation, lower prices, lower liquidations values, and are purchased by lower-income consumers.

After discontinuation, down payments are higher by $88 and LTV ratios increase by two percentage points. These two findings are consistent with a model of the auto market in which IBL plays a meaningful part and low-income borrowers rely relatively more heavily on it. In a sample of

[24] Source: https://fred.stlouisfed.org/series/CUSR0000SETA.

defaulted loans, we find that roughly three-fourths of lender recoveries arise from the vehicle (which serves as the collateral for ABL) and the remaining one-fourth comes from the borrower personally (the source of the guarantee in IBL). For vehicles purchased post-discontinuation, physical collateral recoveries as a percentage of the loan balance are 2.7 percentage points lower, while these recoveries are 1.3 percentage points lower for borrowers who experience discontinuation after purchase. These negative estimates show that discontinuations reduce liquidation values, and the gap between the effects is consistent with the claim that depreciation is borrower-dependent. For autos purchased after a discontinuation announcement, the percentage of the loan balance recovered via personal income increases by 1.9 percentage points. The higher personal recoveries on discontinued vehicles may seem surprising given that their purchasers have lower incomes and buy less-expensive vehicles. The model supplies the explanation that low-income borrowers make greater use of IBL and must therefore use their personal resources, rather than the collateral value of the vehicle, to cover missing payments in the event of default.

In the post-financial crisis period, securitization market issuances have increased relatively more for ABL than for IBL forms of financing. This shift may limit relative credit access for the lower-income borrowers who rely on IBL. A resulting restriction on the ability of economically disadvantaged consumers to purchase cars may have wide-ranging implications for their welfare. Our results indicate that innovations that aid lenders in monitoring borrower incomes are likely to be especially helpful for less wealthy consumers who seek auto financing.

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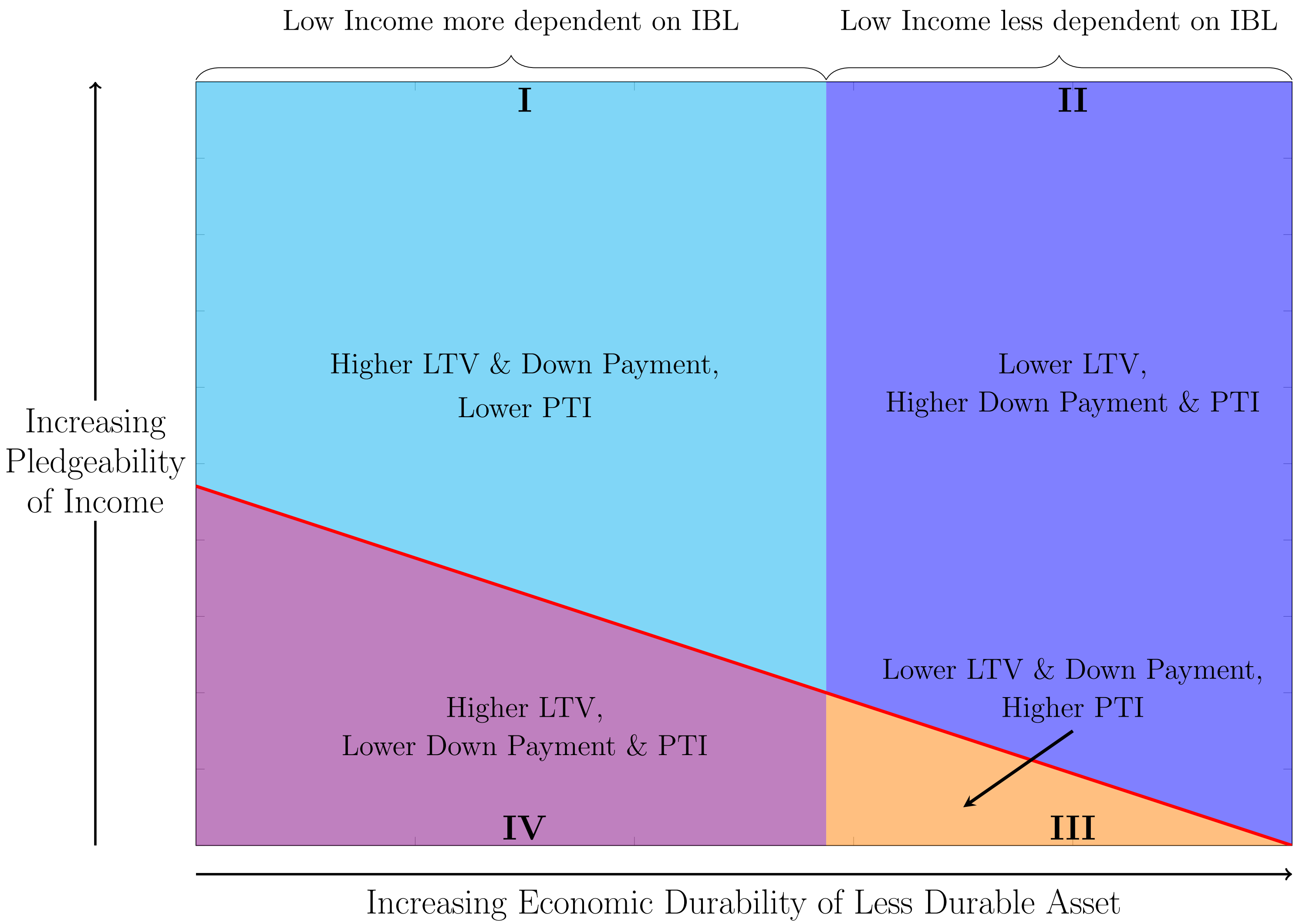

Figure 1: **Visualization of model equilibria - Less Durable relative to More Durable Asset.** This figure presents four potential equilibrium outcomes of the LTV, down payment, and PTI of the less durable asset relative to the more durable asset. The y-axis is income pledgeability (θ_I), the x-axis is the economic durability of the less durable asset (δ). Model parameters are: $I_H = 2$, $I_L = 1.15$, $\theta_G = 0.6$, and $\gamma = 1$.

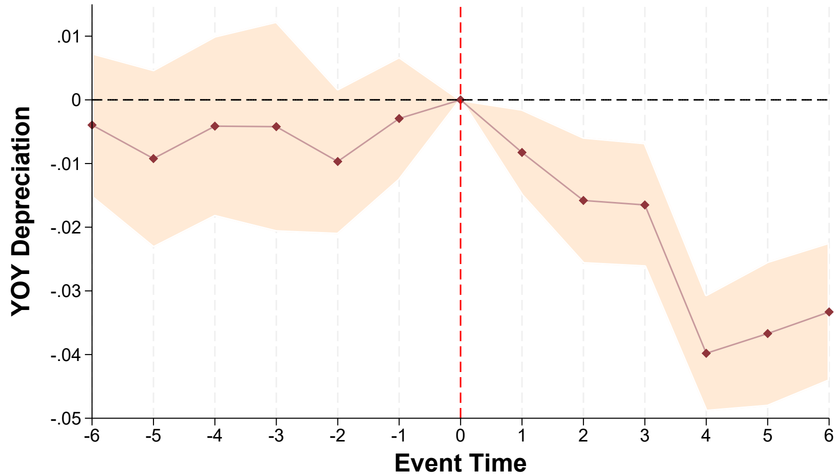

Figure 2: **YoY Depreciation against Event Time.** This figure presents differences in the year-over-year depreciation across vehicles (models & makes) that were discontinued and those that were not. The plot displays the regression coefficients for timing indicators around the year the model was discontinued (discontinuation year=0). The dependent variable is the percentage change in the average annual wholesale value of the vehicle as reported by Black Book. Included fixed effects are Make/Model x Vintage Year and Contract Year x Parent Company.

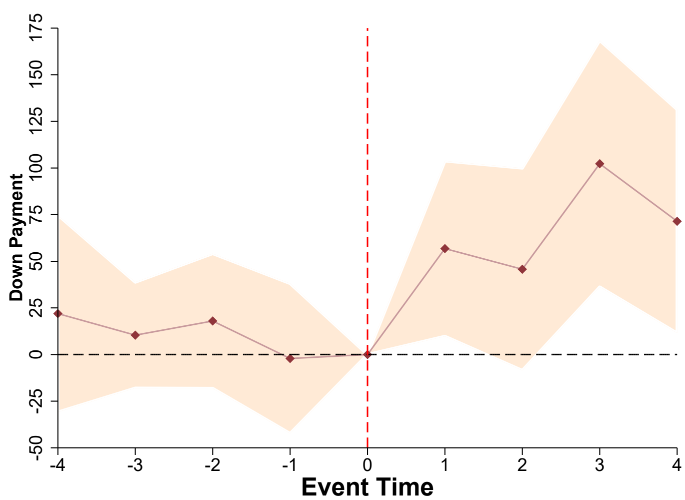

Figure 3: **Down Payment against Event Time.** This figure presents differences in the down payments across vehicles (models & makes) that were discontinued and those that were not. The plot is the regression coefficients for timing indicators around the year the model was discontinued (discontinuation year=0). The dependent variable is the down payment for the vehicle. Included fixed effects are Make/Model x Vintage Year, Dealership, and Contract Year x Parent Company.

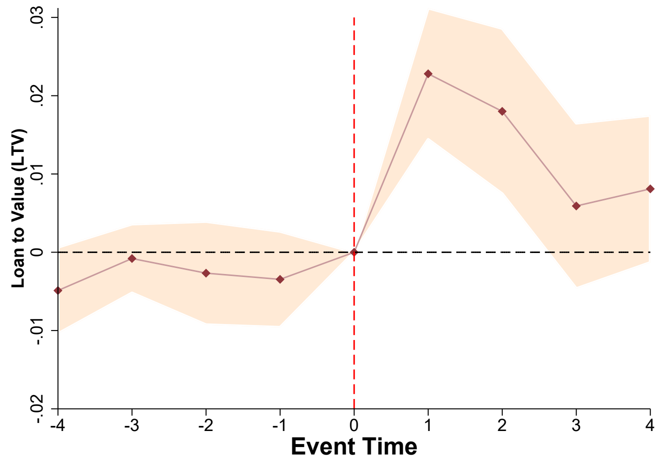

Figure 4: **LTV against Event Time.** This figure presents differences in the loan to value (LTV) across vehicles (models & makes) that were discontinued and those that were not. The plot is the regression coefficients for timing indicators around the year the model was discontinued (discontinuation year=0). The dependent variable is the loan amount divided by the reported vehicle value to the lender for the vehicle. Included fixed effects are Make/Model x Vintage Year, Dealership, and Contract Year x Parent Company.

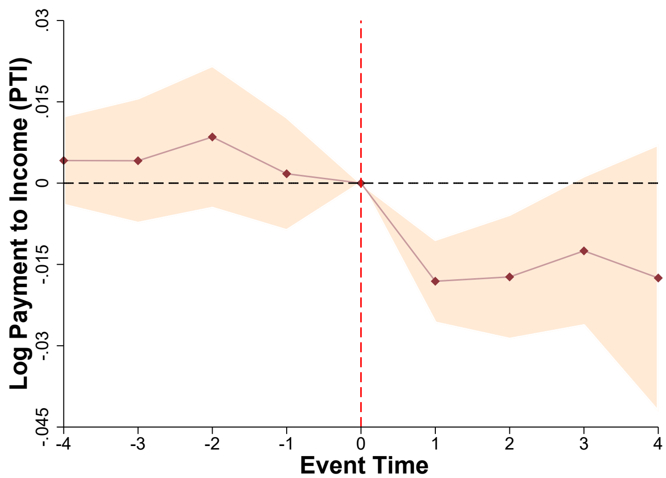

Figure 5: **PTI against Event Time.** This figure presents differences in the log of the payment to income ratio (PTI) across vehicle make-models that were discontinued and those that were not. The plot is the regression coefficients for timing indicators around the year the model was discontinued (discontinuation year=0). The dependent variable is the log of the borrower's monthly payment to the borrower's monthly income. Included fixed effects are Make/Model x Vintage Year, Dealership, borrower income decile, and Contract Year x Parent Company.

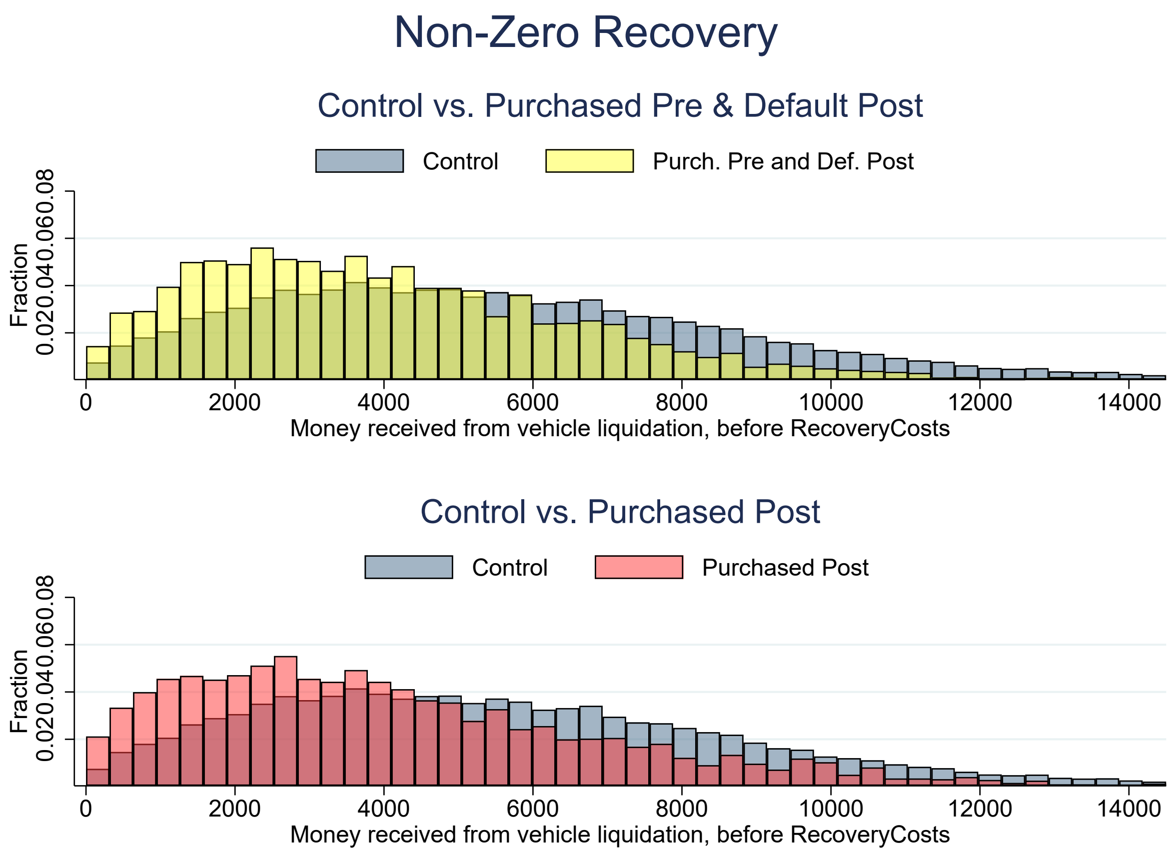

Figure 6: **Vehicle Default Recovery Conditional on Purchase Timing.** This figure presents a histogram of the gross recovered vehicle value of defaulted loans conditional on the purchase timing and having positive vehicle recovery. The treated group in the top panel consists of loans purchased prior to discontinuation but defaulted after discontinuation and the treated group in the bottom panel consists of loans of vehicles purchased post-discontinuation. The control group in both panels consists of vehicles that were not ever discontinued and vehicles that were purchased no more than 2 years prior to vehicle discontinuation and defaulted prior to discontinuation.

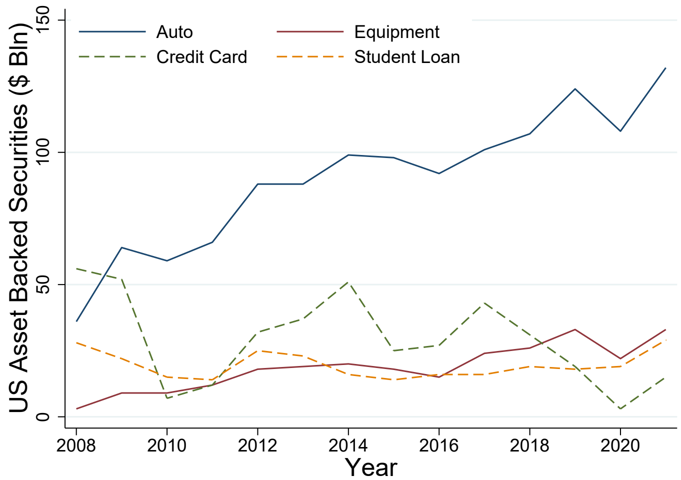

Figure 7: **US Asset Backed Securitization** This figure presents the total annual issuance of US Asset Backed Securities in the United States for four categories (auto, equipment, student loans, and credit cards). All amounts are billions of U.S. Dollars. All data is from Bloomberg, Dealogic, Thomson Reuters; www.sifma.org, March 28 2022.

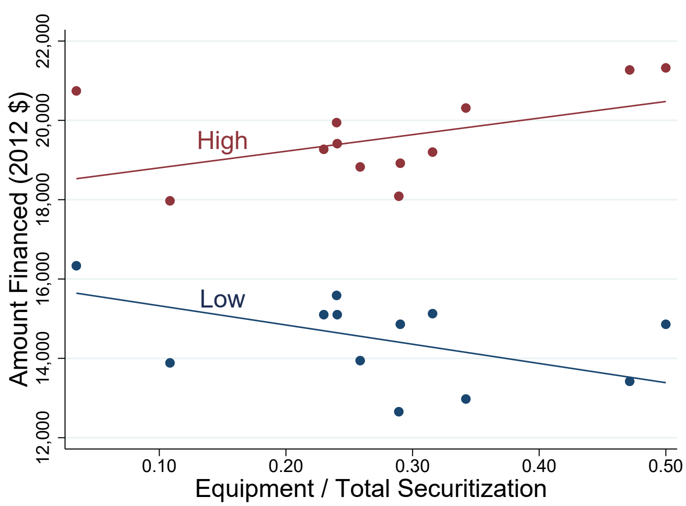

Figure 8: **Amount Financed to Asset Based Securitization.** This figure presents the average amount financed across the equipment to total securitization ratio across the lowest and highest borrower income quartiles for years spanning 2008 to 2021. Amount financed is deflated to 2012 dollars using the GDP deflator from the St. Louis Federal Reserve. All securitization data is from Bloomberg, Dealogic, Thomson Reuters; www.sifma.org, March 28 2022.

Table 1: **Summary Statistics.** This table reports summary statistics for the variables used in the analysis. Panel A provides statistics from Black Book based on annual averages. Panel B provides summary statistics for the loan-level data. Appendix Table B.1 describes the variables. All continuous variables are winsorized at the 1st and 99th percentile.

	Mean	S.D.	25th Pctile	Median	75th Pctile	Obs
Panel A: Black Book Data						
Post Discontinuation (=1)	0.21	0.41	0.00	0.00	0.00	53723
Wholesale Value ($)	12493	10955	4206	9667	17165	53723
YOY Depreciation (%)	-0.15	0.09	-0.20	-0.15	-0.09	48413
Wholesale Value – New ($)	23395	10846	15363	20647	29020	3665
Panel B: Loan Data						
Borrower						
Income ($)	4404	1800	3089	3960	5260	291977
Credit Score	532.12	50.08	497.33	531.00	566.00	317966
Chapter 7 Bankruptcy (=1)	0.21	0.41	0.00	0.00	0.00	334204
Chapter 13 Bankruptcy (=1)	0.08	0.27	0.00	0.00	0.00	334204
Homeowner (=1)	0.06	0.24	0.00	0.00	0.00	334204
Vehicle						
Post Discontinuation (=1)	0.05	0.22	0.00	0.00	0.00	334204
Vehicle Mileage ('000)	39.19	21.65	24.99	38.30	52.85	331000
Dealer Profit ('000 $)	4.33	2.45	2.62	4.21	6.04	334176
Purchase & Loan						
Wholesale Value ($)	13547	4270	10675	13025	15775	334196
Wholesale Value ($) – New	18876	4263	15898	18371	21240	290453
Purchase Price ($)	17087	4797	1398	16739	19686	326809
Scaled Price (%)	72.42	18.38	59.68	70.34	83.05	290446
Down Payment ($)	1025	1134	0	800	1500	333936
LTV	1.29	0.18	1.18	1.29	1.42	334092
APR (%)	19.34	2.80	17.95	19.49	21.00	334204
Loan Term (months)	67.59	7.22	66.00	72.00	72.00	334196
Payment to Income	0.10	0.03	0.08	0.11	0.13	291979
Default (=1)	0.26	0.44	0.00	0.00	1.00	334204
Time to Default (Months)	30.91	17.52	17.00	28.00	42.00	86033
Gross Default ($)	12430	5845	8636	13055	16556	82440
Vehicle Recovery ($)	3483	3331	0.00	2921	5895	77325
Income Recovery ($)	1170	2503	0.00	0.00	648	80989

Table 2: **Vehicle Depreciation and Model Discontinuation.** This table reports estimates from panel regressions of the average vehicle reported value wholesale value from Black Book on model discontinuation and event time indicators. In columns (1) and (2), the dependent variable is the vehicle *YoY Depreciation*, the percentage change in the average wholesale value as reported by Black Book. In columns (3) and (4), the dependent variable is the vehicle's *wholesale*, the average vehicle wholesale value reported by Black Book. *Post-Discontinuation* is an indicator for all years after the transaction year for which the brand or model of the vehicle was discontinued. Event time indicators are relative to the discontinuation date, with discontinuation occurring at time 0, as in Figure 2. Fixed effects are as described in the table. Parent fixed effects relate to the parent company of the make and model. Robust standard errors are clustered by vehicle make. The t-statistics are shown in parentheses below the coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	YoY Depreciation (%)		Wholesale ($)	
	(1)	(2)	(3)	(4)
Post Discontinuation (=1)	-0.012**		-1068.22**	
	(-2.60)		(-2.50)	
Event Time = -6		-0.004		232.73
		(-0.71)		(0.50)
Event Time = -5		-0.009		3.99
		(-1.33)		(0.01)
Event Time = -4		-0.004		100.95
		(-0.59)		(0.24)
Event Time = -3		-0.004		3.21
		(-0.52)		(0.01)
Event Time = -2		-0.010*		-181.96
		(-1.71)		(-0.59)
Event Time = -1		-0.003		-363.17
		(-0.61)		(-1.19)
Event Time = 1		-0.008**		-1055.13***
		(-2.46)		(-3.00)
Event Time = 2		-0.016***		-1544.99***
		(-3.22)		(-4.61)
Event Time = 3		-0.017***		-1860.30***
		(-3.42)		(-5.74)
Event Time = 4		-0.040***		-2035.32***
		(-8.74)		(-6.80)
Event Time = 5		-0.037***		-1959.30***
		(-6.51)		(-7.32)
Event Time = 6		-0.033***		-1943.10***
		(-6.17)		(-7.22)
Vehicle Model x Vintage FEs	Yes	Yes	Yes	Yes
Parent x Contract Year FEs	Yes	Yes	Yes	Yes
Observations	48086	48086	53496	53496
Adjusted R^2	0.369	0.375	0.887	0.888

Table 3: **Vehicle Wholesale Value and Model Discontinuation.** This table reports estimates from panel regressions of the vehicle's reported value on model discontinuation. In columns (1) to (3), the dependent variable is the vehicle *Wholesale Value*, the wholesale value of the vehicle reported to the lender at loan origination. In columns (4) and (5), the dependent variable is the vehicle's *Scaled Price*, the vehicle wholesale value reported to the lender at origination over the average of the given vehicle model and year wholesale value when new. *Post-Discontinuation* is an indicator for all years after the transaction year for which the brand or model of the vehicle was discontinued. Robust standard errors are clustered by vehicle make. The t-statistics are shown in parentheses below the coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Wholesale Value ($)			Scaled Price (%)		
	(1)	(2)	(3)	(4)	(5)	(6)
Post Discontinuation (=1)	-297.56**	-371.27***	-277.88**	-3.89***	-3.88***	-3.16***
	(-2.58)	(-3.52)	(-2.57)	(-4.59)	(-4.65)	(-6.35)
Log Income		1205.65***	1178.17***		5.99***	5.63***
		(27.56)	(22.00)		(28.79)	(23.56)
Credit Score		1.16***	1.36***		0.01***	0.01***
		(6.24)	(5.81)		(5.05)	(4.78)
Ch. 7 Bankruptcy (=1)		119.93***	165.67***		0.54***	0.80***
		(8.33)	(17.43)		(7.93)	(16.67)
Ch. 13 Bankruptcy (=1)		-139.91***	-171.88***		-0.72***	-0.81***
		(-4.20)	(-4.48)		(-4.68)	(-4.38)
Homeowner (=1)		-49.33**	-30.52*		-0.37***	-0.27***
		(-2.61)	(-1.84)		(-3.76)	(-3.10)
Log Mileage			-636.79***			-3.53***
			(-22.88)			(-24.14)
Dealer Profit ('000 $)			-124.56***			-0.60***
			(-10.37)			(-8.84)
Veh. Model x Vintage FEs	Yes	Yes	Yes	Yes	Yes	Yes
Dealer FEs	Yes	Yes	Yes	Yes	Yes	Yes
Parent x Contract Yr. FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	332337	278938	278259	289778	252979	252422
Adjusted R^2	0.771	0.758	0.816	0.673	0.684	0.777

Table 4: **Default Recovery and Model Discontinuation.** This table reports estimates from panel regressions of proxies of the vehicle's residual value. The dependent variables is the *Vehicle Recovery* represents the recovery value that the lender receives from the vehicle liquidation after default over the vehicle's wholesale value at origination. All observations are conditional on default. Columns (3) contains additional fixed effects for both the year of the default interacted with the vehicle model as well as the recovery type. *Post-Discontinuation* is an indicator for all years after the transaction year for which the brand or model of the vehicle was discontinued. Robust standard errors are clustered by vehicle make. The t-statistics are shown in parentheses below the coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Vehicle Recovery (%)	(1)	(2)	(3)
Post Discontinuation (=1)	-1.73***	-2.27***	-1.54***
	(-3.33)	(-4.78)	(-2.85)
Vehicle Model x Vintage FE	Yes	Yes	Yes
Parent x Contract Year FE	Yes	Yes	Yes
Dealership FE	Yes	Yes	Yes
Model x Default Year FE	No	No	Yes
Recovery Type FE	No	No	Yes
Borrower Controls	No	Yes	Yes
Vehicle Controls	No	Yes	Yes
Time to Default Control	No	Yes	Yes
Observations	75507	65959	65135
Adjusted R^2	0.087	0.272	0.580

Table 5: **Borrower Income and Model Discontinuation.** This table reports estimates from panel regressions of borrower income. The dependent variable in columns (1-2) is *Low Income* = 1 an indicator for whether the borrower was in the bottom quartile of income for borrowers in that year. The dependent variable in columns (3-4) is the *Log Income* of the borrower reported to the lender at the time of the origination. The dependent variable in columns (5-6) is the borrower income, and the regression is estimated via Poisson pseudo-likelihood regression. *Post Discontinuation* is an indicator for all years after the transaction year for which the brand or model of the vehicle was discontinued. Robust standard errors are clustered by vehicle make. The reported R^2 in columns (5-6) is the pseudo-R^2 from the Poisson regression. The t-statistics are shown in parentheses below the coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Dep. Var.	Low Income (=1)		Log Income		Income (Poisson)	
	(1)	(2)	(3)	(4)	(5)	(6)
Post Discontinuation (=1)	3.45***	3.57***	-0.01**	-0.01*	-0.02***	-0.02***
	(2.93)	(3.05)	(-2.03)	(-1.96)	(-2.60)	(-2.59)
Vehicle Model x Vintage FE	Yes	Yes	Yes	Yes	Yes	Yes
Parent x Contract Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Dealership FE	Yes	Yes	Yes	Yes	Yes	Yes
Vehicle Controls	No	Yes	No	Yes	No	Yes
Observations	290435	289733	290435	289733	290435	289733
Adjusted R^2	0.141	0.183	0.241	0.281	0.251	0.282

Table 6: **Loan Maturity and Model Discontinuation.** This table reports estimates from panel regressions of the maturity of the loan at origination. The dependent variable *Loan Maturity* is the original maturity of the loan at origination (in months). *Post Discontinuation* is an indicator for all years after the transaction year for which the brand or model of the vehicle was discontinued. Robust standard errors are clustered by vehicle make. The t-statistics are shown in parentheses below the coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Loan Maturity (Months)	(1)	(2)	(3)
Post Discontinuation (=1)	-0.82***	-0.79***	-0.81***
	(-5.64)	(-4.83)	(-5.18)
Vehicle Model x Vintage FEs	Yes	Yes	Yes
Dealer FEs	Yes	Yes	Yes
Parent x Contract Year FEs	Yes	Yes	Yes
Borrower Controls	No	Yes	Yes
Vehicle Controls	No	No	Yes
Observations	332340	278941	278259
Adjusted R^2	0.579	0.369	0.385

Table 7: **Down payment and Model Discontinuation.** This table reports estimates from panel regressions of the vehicle's down payment at origination. The dependent variable is the winsorized vehicle's *Down Payment*, the cash amount that the borrower pays at loan origination. *Post Discontinuation* is an indicator for all years after the transaction year for which the brand or model of the vehicle was discontinued. Robust standard errors are clustered by vehicle make. The t-statistics are shown in parentheses below the coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Down Payment ($)	(1)	(2)	(3)
Post Discontinuation (=1)	85.28***	68.76**	88.34***
	(3.76)	(2.31)	(3.30)
Wholesale Value ($)			0.07***
			(26.77)
Vehicle Model x Vintage FEs	Yes	Yes	Yes
Dealer FEs	Yes	Yes	Yes
Parent x Transaction Year FEs	Yes	Yes	Yes
Borrower Controls	No	Yes	Yes
Vehicle Controls	No	Yes	Yes
Observations	332078	277997	277997
Adjusted R^2	0.208	0.226	0.239

Table 8: **Loan to Value (LTV) and Model Discontinuation.** This table reports estimates from panel regressions of the loan to value (LTV) ratio. The dependent variable in columns (1) to (3) is the *Loan-to-Value* (LTV) ratio, which is the amount financed over the reported wholesale vehicle value. *Post Discontinuation* is an indicator for all years after the transaction year for which the brand or model of the vehicle was discontinued. Robust standard errors are clustered by vehicle make. The t-statistics are shown in parentheses below the coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Loan-to-Value (LTV)	(1)	(2)	(3)
Post Discontinuation (=1)	0.02***	0.02***	0.02***
	(3.63)	(4.06)	(6.74)
Vehicle Model x Vintage FEs	Yes	Yes	Yes
Dealer FEs	Yes	Yes	Yes
Parent x Contract Year FEs	Yes	Yes	Yes
Borrower Controls	No	Yes	Yes
Vehicle Controls	No	No	Yes
Observations	332236	278884	278204
Adjusted R^2	0.352	0.349	0.717

Table 9: **Payment to Income (PTI) and Model Discontinuation.** This table reports estimates from panel regressions of the payment to income ratio of the borrower. The dependent variable is the natural log of the *Payment-to-Income* ratio (PTI) in columns (1-4), which the is borrower's estimated monthly payment over the borrower's reported monthly income, and the PTI ratio in columns (5-8), multiplied by 100 for readability. *Post Discontinuation* is an indicator for all years after the transaction year for which the brand or model of the vehicle was discontinued. Robust standard errors are clustered by vehicle make. The t-statistics are shown in parentheses below the coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Log(PTI)				PTI			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post Discontinuation (=1)	-0.02**	-0.02***	-0.03***	-0.02***	-0.18***	-0.24***	-0.27***	-0.24***
	(-2.51)	(-5.26)	(-6.29)	(-5.36)	(-2.76)	(-6.05)	(-7.64)	(-6.41)
Vehicle Model x Vintage FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Parent x Contract Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealership FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Income Decile FE	No	Yes	No	Yes	No	Yes	No	Yes
Borrower Controls	No	No	Yes	Yes	No	No	Yes	Yes
Vehicle Controls	No	No	Yes	Yes	No	No	Yes	Yes
Observations	290437	290435	278259	278259	290437	290435	278259	278259
Adjusted R^2	0.042	0.528	0.567	0.546	0.054	0.638	0.672	0.660

Table 10: **Vehicle Recovery and Purchase Timing.** This table reports estimates from panel regressions of the vehicle based recovery on defaulted loans. For vehicles that are discontinued or eventually discontinued only vehicles purchased within +/- 2 years of discontinuation are included. In columns (1) to (3), the dependent variable is the *Vehicle Recovery* value. In columns (4) to (6), the dependent variable is the percent of the vehicle's original wholesale value recovered via vehicle recovery. In columns (7) to (9), the dependent variable is the percent of the balance of a defaulted loan recovered via vehicle recovery. All recovery values are net of fees. *Post-Discontinuation* is an indicator for all years after the transaction year for which the brand or model of the vehicle was discontinued. *Purchased Pre., Default Post* is an indicator for if the vehicle was purchased prior to discontinuation but the loan defaulted after discontinuation. Robust standard errors are clustered by vehicle make. The t-statistics are shown in parentheses below the coefficient estimates. The F-statistic and associated p-values for whether *Post-Discontinuation* is equal to *Post-Discontinuation* is reported in the bottom row. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Veh. Rec. ($)			Veh. Rec./Default (%)		
	(1)	(2)	(3)	(4)	(5)	(6)
Post Discontinuation (=1)	-261.83***	-432.32***	-367.82***	-1.74***	-2.94***	-2.71***
	(-4.49)	(-4.30)	(-3.84)	(-6.02)	(-5.39)	(-4.70)
Purchased Before, Defaulted After (=1)		-194.03**	-163.63*		-1.36**	-1.26*
		(-2.25)	(-2.00)		(-2.14)	(-1.94)
F-Stat (Post Disc. = Purch. Before, Def. After)		15.31	15.35		23.83	22.43
		(0.0004)	(0.0004)		(0.0000)	(0.0000)
Vehicle Model x Vintage FE	Yes	Yes	Yes	Yes	Yes	Yes
Parent x Contract Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Dealership FE	Yes	Yes	Yes	Yes	Yes	Yes
Parent x Default Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Recovery Type FE	Yes	Yes	Yes	Yes	Yes	Yes
Borrower Controls	No	No	Yes	No	No	Yes
Vehicle Controls	No	No	Yes	No	No	Yes
Time to Default Control	No	No	Yes	No	No	Yes
Observations	58531	58531	56726	58520	58520	56717
Adjusted R^2	0.565	0.565	0.577	0.502	0.502	0.507

Table 11: **Income Recovery and Model Discontinuation.** This table reports estimates from panel regressions of the income based recovery on defaulted loans. In columns (1) to (3), the dependent variable is the dollar value of the *Income Recovery* amount net of fees. In columns (4) and (5), the dependent variables is the percent of the balance of a defaulted loan recovered via the income of the borrower net of fees. *Post-Discontinuation* is an indicator for all years after the transaction year for which the brand or model of the vehicle was discontinued. *Gross Default* is the remaining portion of the loan outstanding at default. Robust standard errors are clustered by vehicle make. The t-statistics are shown in parentheses below the coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Inc. Rec. ($)			Inc. Rec./Default (%)	
	(1)	(2)	(3)	(4)	(5)
Post Discontinuation (=1)	110.40*	116.30*	145.04**	1.70*	1.89**
	(1.79)	(1.86)	(2.32)	(1.94)	(2.13)
Gross Default Amount ('000 $)			51.89***		
			(10.78)		
Vehicle Model x Vintage FE	Yes	Yes	Yes	Yes	Yes
Parent x Contract Year FE	Yes	Yes	Yes	Yes	Yes
Dealership FE	Yes	Yes	Yes	Yes	Yes
Model x Default Year FE	Yes	Yes	Yes	Yes	Yes
Recovery Type FE	Yes	Yes	Yes	Yes	Yes
Borrower Controls	No	Yes	Yes	No	Yes
Vehicle Controls	No	Yes	Yes	No	Yes
Time to Default Control	No	Yes	Yes	No	Yes
Observations	71440	69341	69340	71427	69330
Adjusted R^2	0.102	0.107	0.113	0.112	0.114

Internet Appendix for: "Collateral Damage: Low-Income Borrowers Depend on Income-Based Lending"

Appendix A. Theoretical Setup

To illustrate the effects of a durability shock on the consumer financing of asset purchases, we provide a simple model of financing. The key difference between our model and others that examine the effects of durability (e.g., Rampini, 2019), is that we allow for both asset-based lending (ABL) as well as income-based lending (IBL). We show that the addition of a sufficient level of IBL combined with lower income borrowers depending relatively more on IBL is central to explaining our empirical results. The model consists of two-periods and three agents (consumers, sellers, and lenders). All agents are risk neutral.

Appendix A.1. Consumers and Goods

There are two types (low and high income) of consumers $i \in \{L, H\}$. Both consumer types have income I_i in each period, but differ in the level of their incomes, where $I_H > I_L > 0$. We further assume that the difference in incomes is not too large, so $2I_L > I_H$. Consumers can purchase one of two types of goods $G \in \{MD, LD\}$, which we denote more durable and less durable. More durable goods have value $2\gamma > 0$ in the first period, and value γ in the second period. Less durable goods have value $(1+\delta)\gamma$ in the first period and value $\delta\gamma$ in the second period, where $\delta \in (0, 1)$ represents the residual value of the less durable good relative to the more durable good. The central difference between the goods is their degree of depreciation. The seller (e.g., a car dealership) of the good earns some profit κ on the sale, meaning the combined price of a good is κ plus its value.

Consumers face no shocks, information is full, and consumers prefer current consumption over delayed consumption. Note the latter assumption is valid if, for example, the lender is more patient than the consumer or if the lender has more diversified income. Moreover, both consumer types would always prefer the more durable good if they can afford it. This assumption holds if the consumer gets the same marginal utility from each good, meaning the benefit is relatively cheaper given the fixed margin κ that the seller of the asset charges. We further presume that purchasing the less durable good is attractive relative to purchasing nothing, even accounting for consumers' subjective preference for first period consumption.

Appendix A.2. Pledgeability of Assets and Income

Consumers can borrow from a competitive set of lenders to finance their purchase. As in Rampini (2019), due to the limited pledgeability of assets, lenders require collateral. The consumer can pledge the good's residual value in the second period (i.e., ABL) as well as their income in the second period (i.e., IBL). The pledgeability of assets and income is denoted by $\{\theta_G, \theta_I\}$, where both are bounded between $[0, 1)$, which represent the fraction of the asset and income, respectively, that can be pledged as collateral. Naturally, as the pledgeability of income θ_I (assets θ_G) tends towards 0, the financing will increasingly consist of ABL (IBL). The pledgeability of income reflects the potential for the to recover the remaining portion of the loan in default from sources of income (e.g., wage garnishment): a fraction up to θ_I of the borrower's second-period income may be seized by the lender. The pledgeability of assets reflects the lender's claim on the assets. In the second period, the lender may repossess the asset and receive a fraction θ_G of its residual value. In equilibrium, the borrower will instead sell the asset for its residual value and make the pledged payment. For simplicity, we assume that the risk-free rate is 0. Consumers face no sanction or cost from defaulting other than the loss of any pledged income or the good.

To examine the interesting parameter space of the model, we assume that high (low)-income consumers can (cannot) afford the more durable good if they borrow their maximum feasible limit

$$\theta_I I_L + \theta_G \gamma + I_L < 2\gamma + \kappa < \theta_I I_H + \theta_G \gamma + I_H. \tag{A1}$$

Low income consumers, however, can afford the less durable good,

$$\theta_G \delta\gamma + \theta_I I_L + I_L > (1+\delta)\gamma + \kappa. \tag{A2}$$

We assume that κ is such that equations A1 and A2 hold.

Appendix A.3. Analysis

We now solve for the loan characteristics of low income and high income consumers. Specifically, we examine the (1) down payments, (2) loan-to-value ratios, and (3) payment-to-income ratios of the two types of consumers and then examine the effects of allowing the pledgeability of income θ_I and the degree of depreciation δ to vary.

Appendix A.3.1. Down Payments

Given the pledgeability constraints and the markup, consumers need to pay for some portion of the good in period 1 using their first period income I_i. Under the assumption that consumers prefer to maximize first period consumption, the consumer will seek to minimize their down payment and maximize their borrowing. We examine the down payments for consumers who purchase the more durable and less durable good separately.

The down payment for the consumer who purchases the more durable good is

$$\kappa + 2\gamma - \gamma\theta_g - I_i\theta_I. \tag{A3}$$

The down payment for the consumer who purchases the less durable good is

$$\kappa + (1+\delta)\gamma - \gamma\delta\theta_g - I_i\theta_I. \tag{A4}$$

If income is sufficiently pledgeable, specifically if

$$\theta_I > \frac{\gamma(1-\delta)(1-\theta_g)}{I_H - I_L}, \tag{A5}$$

then the down payment is greater for the less durable good purchased by the low-income consumer, otherwise the down payment will be greater for the more durable good. This condition states that the income pledgeability constraint weakens when the difference between the non-pledgeable value of the assets is smaller than the difference in the borrower incomes. As the residual value of the less durable good, δ increases, it becomes relatively more expensive and thus requires a higher down-payment, matching the intuition of Rampini (2019). However, holding the residual value constant, when income pledgeability is high, the down payment of the higher income borrower is lower since they can pledge more of their income when borrowing. Thus, whether the down payment of the less durable good is higher depends on the relative difference in the non-pledgeable portion of the assets to the difference in the incomes.

The intuition is that if the residual value is too small, then the *price effect* (i.e., the lower price and down payment from the difference in depreciation) will dominate *the income pledgeability effect* (i.e., lower income supporting smaller income-based loan and therefore a higher down payment).

Appendix A.3.2. Loan-to-Value (LTV) Ratio

We now turn to the loan-to-value (LTV) ratios. The collateral value of the more durable and less durable good to the lender, i.e., the value of the good they can collect on next period, is γ or $\delta\gamma$.

Again, we examine the LTVs for the purchase of the more durable and less durable goods when both ABL and IBL are available. The LTV for the high-income consumer who purchases the more durable good is

$$\frac{\gamma\theta_g + I_H\theta_I}{\gamma}. \tag{A6}$$

The LTV for the low-income consumer who purchases the less durable good is

$$\frac{\gamma\delta\theta_g + I_L\theta_I}{\delta\gamma}. \tag{A7}$$

If low-income borrowers are more dependent on income-based lending, specifically if

$$\delta < \frac{I_L}{I_H}, \tag{A8}$$

then the LTV is higher for the less durable good, otherwise the LTV is higher for the more durable good. This condition is equivalent to saying that the ratio of IBL to ABL for low-income borrowers is higher than that for high-income borrowers, i.e.,

$$\frac{\theta_I I_L}{\theta_G \delta \gamma} > \frac{\theta_I I_H}{\theta_G \gamma}. \tag{A9}$$

The intuition, for the condition is that the income portion of the financing must be more important for the low-income borrower. If IBL is relatively more important for the low-income borrower, then their higher IBL dependence will outweigh the relatively smaller amount they get from borrowing against a lower-valued asset.

Appendix A.3.3. Payment-to-Income (PTI) Ratio

The payment to income ratio is always lower for the low-income purchaser as long as the low-income purchases is more dependent on income-based lending, which is satisfied by equation A8 above. It does not depend on the degree of the pledgeability constraints.[25]

The overall restrictions for δ and θ_I for the down payment, LTV, and PTI results are then

$$1 > \theta_I > \frac{\gamma(1-\delta)(1-\theta_g)}{I_H - I_L} \tag{A10}$$

$$0 < \delta < \frac{I_L}{I_H}. \tag{A11}$$

Appendix A.3.4. Discussion

The existence of constraints on both the pledgeability of income and the importance of the income-based lending provide key implications for empirical tests. Specifically, if less durable goods have higher LTVs, higher downpayments, lower PTIs, and are purchased by lower-income consumers, then a key implication of the model is that the lower-income consumers are more dependent on income-based lending and that it must be relatively important for auto-lending.

Figure 1 presents a graphical illustration of the results. There are four regions which relate to where the down payment, LTV, and PTI for the less durable good purchased by the low-income consumer are relative to the more durable good purchased by the high-income consumer. As income pledgeability θ_I increases, IBL becomes a relatively large portion of financing to purchase the asset. As δ decreases, IBL becomes relatively more important for the low-income borrower as the residual value of the less durable asset is declining, reducing the ability to rely on ABL. When θ_I is relatively high and δ is low, the light blue region (I), the LTV and down payment are higher for the less durable asset, and the PTI is lower. The level of θ_I to support higher down payments for the less durable asset, dark red line, must increase to offset the lower price of the less durable asset, otherwise the down payment is lower, the purple region (IV). If δ is above a

[25] Note that the payment to income ratio for both types of consumers will be higher with more IBL (higher θ_I), but since income is in the numerator and denominator of the ratio, the relative level of PTI only depends on the degree of residual value relative to the ratio of incomes.

certain level, then low-income consumers rely relatively more on ABL and in return the LTV is lower and the PTI is higher, the dark blue (II) and orange regions (III).

Appendix A.4. Extension to Include Borrower-Dependent Depreciation

We can extend the model to consider how differences in borrower incomes affects the depreciation of the asset. For instance, borrowers who are liquidity constrained due to lower incomes may forgo periodic maintenance of the asset, resulting in more rapid depreciation and thus a lower residual value.

We make the following additional assumptions. First, depreciation due to the borrower attributes (high or low-income) is represented in reduced form by $\psi_i \geq 0$ for $i \in \{L, H\}$. Second the depreciation is additive and independent of the asset type, such that the value of the asset in the second period (the residual value) is $\gamma(\delta_G - \psi_i)$ for $G \in \{MD, LD\}$ and $i \in \{L, H\}$. Third borrower based depreciation is not so high that the asset has a non-positive recovery value ($\delta_G - \psi_i > 0$). Finally, we assume that the borrower's type does not affect the purchase price of the asset only its residual value (i.e., all buyers face the same sticker price for a given asset). We maintain all other assumptions from the baseline model.

Given the above, we can now rewrite equations (A3)-(A4) and (A6)-(A7), for the down payment and LTV equations, respectively, for the different assets and borrower types. The down payment for the consumer who purchases the more durable good is

$$\kappa + 2\gamma - \gamma(1 - \psi_i)\theta_g - I_i\theta_I. \tag{A12}$$

The down payment for the consumer who purchases the less durable good is

$$\kappa + (1 + \delta)\gamma - \gamma(\delta - \psi_i)\theta_g - I_i\theta_I. \tag{A13}$$

The LTV for the consumer who purchases the more durable good is

$$\frac{(1 - \psi_i)\gamma\theta_g + I_i\theta_I}{(1 - \psi_i)\gamma}. \tag{A14}$$

The LTV for the consumer who purchases the less durable good is

$$\frac{\gamma(\delta - \psi_i)\theta_g + I_i\theta_I}{(\delta - \psi_i)\gamma}. \tag{A15}$$

Assuming that the borrower-dependent depreciation is higher for L-type borrowers (i.e., $\psi_L > \psi_H \geq 0$), we can reformulate equations (A5) and (A8), the conditions on income pledgeability (θ_I) and asset-based depreciation (δ). Specifically, if income is sufficiently pledgeable,

$$\theta_I > \frac{\gamma[(1 - \delta)(1 - \theta_g) - \theta_g(\psi_L - \psi_H)]}{I_H - I_L}, \tag{A16}$$

then the down payment is greater for the less durable good purchased by the low-income consumer, otherwise the down payment will be greater for the more durable good. Relative to equation (A5), we can see that the income level of the pledgeability condition is now lower (setting $\psi_L = \psi_H = 0$ reproduces equation A5). The intuition is that the additional gap between depreciation due to borrower types increases the depreciation differential between the equilibrium asset purchases of the borrower types, further reducing the size of the asset-based portion of the loan for low-income borrowers. Consequentially, either the low-income borrowers must make even higher down payments or the degree that income pledgeability matters for down payment differentials is smaller, relative to the base case without borrower-dependent depreciation.

In addition, if low-income borrowers are more dependent on income-based lending, specifically if

$$\delta < \frac{I_L(1-\psi_H)}{I_H} + \psi_L, \tag{A17}$$

then the LTV is higher for the less durable good, otherwise the LTV is higher for the more durable good. Note, that when $\psi_L > \psi_H \geq 0$, the degree of asset-based depreciation difference necessary to induce high LTVs for less durable goods purchased by low-income borrowers is smaller relative to the baseline model (or equivalently the δ that satisfies this equation is closer to 1). However, this condition is still equivalent to saying that the ratio of IBL to ABL for low-income borrowers is higher than that for high-income borrowers, i.e.,

$$\frac{\theta_I I_L}{\theta_G(\delta - \psi_L)\gamma} > \frac{\theta_I I_H}{\theta_G(1-\psi_H)\gamma}. \tag{A18}$$

The intuition for this result is similar to the baseline model: the income portion of the financing remains more important for the low-income borrower. If IBL is relatively more important for the low-income borrower, then their higher IBL dependence still outweighs the comparatively smaller amount of financing that they derive from borrowing against a lower-valued asset. In this extension the collateral value of the asset is even lower for low-income borrower, which further reduces the ABL portion of the loan, and thus all else equal increases the importance of IBL for the low-income borrower. Thus, similar to the down payment, this condition is more easily satisfied when there is also a depreciation differential due to borrower type.

By similar logic, the payment to income ratio is also lower for the low-income purchaser with borrower-dependent depreciation as long as the low-income purchases is more dependent on income-based lending, which is satisfied by equation A17 above and if the low-income borrower-dependent depreciation is higher ($\psi_L > \psi_H$). Relative to the baseline model, the denominator is the same, but the numerator for the low-income borrower is further reduced by the additional greater depreciation due to the borrower-based depreciation. Therefore, if the PTI is lower for the low-income borrower in the baseline model, *ceteris paribus*, it will be even further reduced if the low-income borrower-dependent depreciation is higher ($\psi_L > \psi_H$).

For completeness we recreate Figure 1, under the same parameter space but with the additional borrower-based depreciation. For illustration, we set $\psi_H = 0$ and $\psi_L = 0.1$.

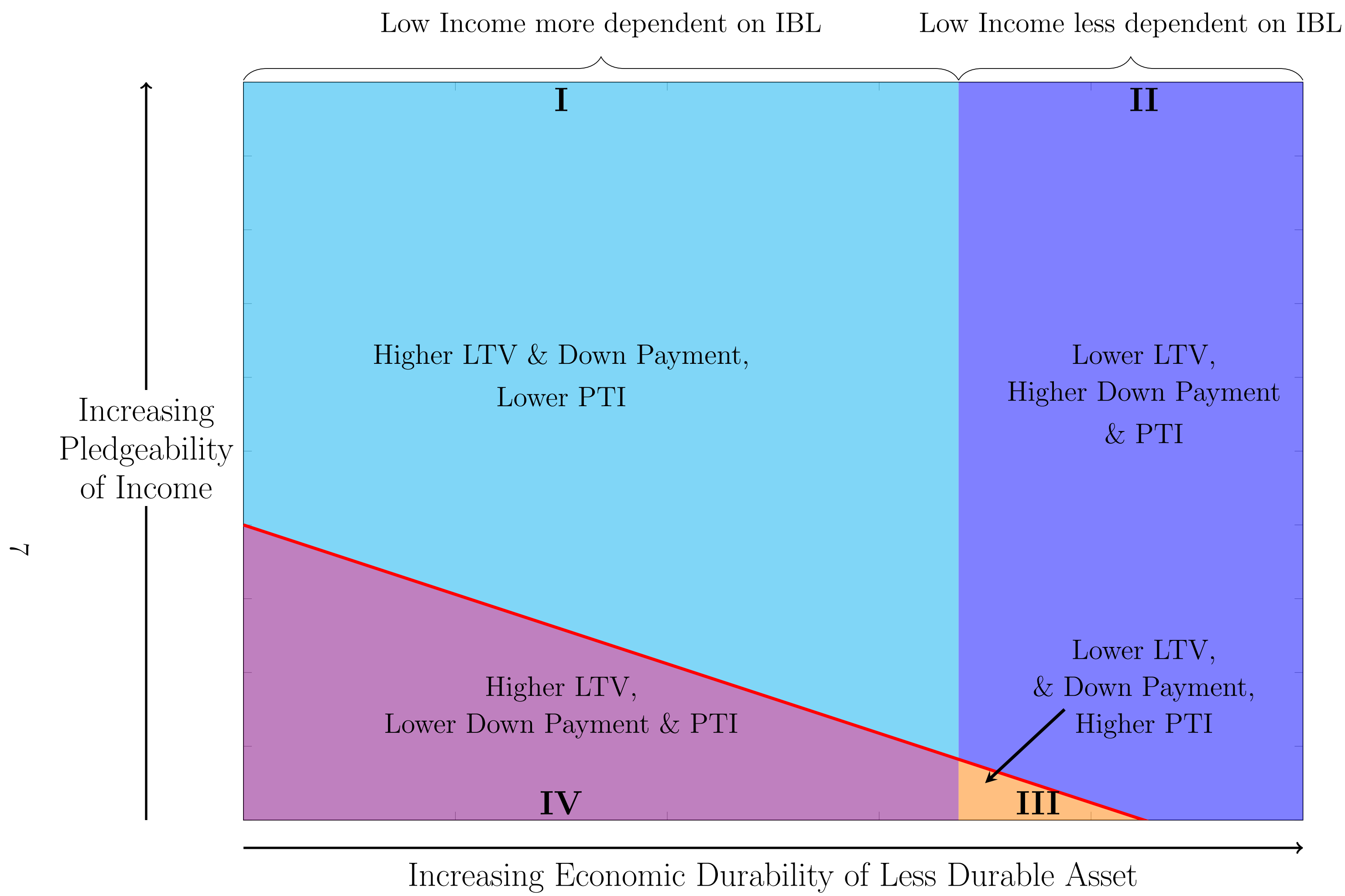

Figure B.1: **Visualization of model extension equilibria - Less Durable relative to More Durable Asset.** This figure presents four potential equilibrium outcomes of the LTV, down payment, and PTI of the less durable asset relative to the more durable asset. The y-axis is income pledgeability (θ_I), the x-axis is the economic durability of the less durable asset (δ). Model parameters are: $I_H = 2$, $I_L = 1.15$, $\theta_G = 0.6$, $\gamma = 1$, $\psi_H = 0$, and $\psi_L = 0.1$.

We highlight two differences between the figures. First the red line is shifted down, indicating that the income pledgeability threshold for down payments is lower. Second the split between low income borrowers being more dependent versus less dependent on IBL is shifted right (the vertical divide in the chart between regions I, IV and II, III), indicating the threshold for the physical depreciation differential is weaker (i.e., the difference in the asset-based depreciation rates of the two assets can be smaller). In return, the light-blue area of the figure is larger, and the orange area is clearly smaller. The purple region and dark blue regions depend on the parameter specifications and whether the threshold for the pledgeability shifts down more than the threshold for the dependence on IBL shifts right. The key take-away is that the region with High LTV and down payments and lower PTI is larger if we allow for depreciation to depend on both the asset and borrower types and assume that low-income borrowers have greater borrower based depreciation.

Appendix B. Supporting Figures and Tables

Table B.1: **Definitions of variables**. The table contains the definitions of all variables used throughout the paper, listed alphabetically.

Variable	Definition
Blackbook Data	
Vehicle Age	Age of the vehicle since vintage year
Wholesale Value – New	Average wholesale value for a make-model-year when new
Wholesale Value	Average wholesale value for a make-model-year
YoY Depreciation	Annual percentage change in the vehicle's wholesale value
Loan Data	
Amount Financed ($)	Total amount of loan at origination
APR (%)	Annualized APR of the loan at origination
Chapter 13 Bankruptcy (=1)	Indicator if the borrower record had a Ch. 13 bankruptcy
Chapter 7 Bankruptcy (=1)	Indicator if the borrower record had a Ch. 7 bankruptcy
Credit Score	Credit score of the borrower at origination
Dealer Profit ('000 $)	Dealer profit from the sale of the vehicle
Default (=1)	Indicator if borrower defaulted on loan
Down Payment ($)	Cash amount borrower paid at loan origination
Gross Default ($)	Remaining portion of the loan outstanding at default
Homeowner (=1)	Indicator if borrower owned their own home
Income	Borrower's reported monthly income
Income Recovery ($)	Post-default collections income net of fees
Income Recovery / Default (%)	Income Recovery /Gross Default
Loan Maturity (months)	Term of the loan (in months) at origination
Log (PTI)	Natural log of Payment to Income
Log Income	Natural log of borrower income
Low Income (=1)	Indicator if borrower is in lowest income quartile by year
LTV	Dollar amount of the loan at origination / Wholesale value
Payment to Income	Borrower's monthly payment / borrower's monthly income
Post Discontinuation (=1)	Indicator for all years after the transaction year for which the brand or model of the vehicle was discontinued
Purchase Price ($)	Purchase price of the vehicle as reported to the lender
Purchased Before, Defaulted After (=1)	Indicator if borrower purchased vehicle prior to discontinuation and defaulted after discontinuation
Scaled Price (%)	Wholesale Value / Wholesale Value – New
Time to Default (months)	Number of months between vehicle purchase and default
Vehicle Age (yrs.)	Vehicle age at sale
Vehicle Mileage ('000)	Vehicle mileage at sale
Vehicle Recovery ($)	Auction proceeds after repossession net of fees
Vehicle Recovery / Default (%)	Vehicle Recovery / Gross Default
Wholesale Value – New	Wholesale value for the given make-model-year when new
Wholesale Value	Wholesale value at the time of origination

Variable	Definition
Other Data	
Equipment Securitization	Total securitized equipment loans in given year, from sifma.org
GDP Deflator	Annual GDP implicit price deflator (Index 2012=100), from Federal Reserve Bank of St. Louis
Total Securitization	Sum of securitized equipment, credit card, and student loans in given year, from sifma.org

Table B.3: **Discontinuation of Models.** This table reports the years of model discontinuations. All dates are from JD Power Associates for the discontinuation for a given model.

Vehicle Make	**Vehicle Model**	**Year**	**Vehicle Make**	**Vehicle Model**	**Year**
Acura	CL	2003	Chevrolet	Cruze	2019
Acura	Integra	2001	Chevrolet	HHR	2011
Acura	RL	2012	Chevrolet	Lumina	2001
Acura	RSX	2006	Chevrolet	Metro	2001
Acura	TL	2014	Chevrolet	Monte Carlo	2007
Acura	TSX	2014	Chevrolet	Prizm	2002
BMW	325	2006	Chevrolet	SSR	2006
BMW	328	2016	Chevrolet	Tracker	2004
BMW	525	2007	Chevrolet	Uplander	2008
BMW	535	2016	Chevrolet	Venture	2005
BMW	550	2016	Chrysler	200	2017
BMW	Z3	2002	Chrysler	300M	2004
Buick	Cascada	2019	Chrysler	Aspen	2009
Buick	Century	2005	Chrysler	Concorde	2004
Buick	LeSabre	2005	Chrysler	Crossfire	2008
Buick	Lucerne	2011	Chrysler	PT Cruiser	2010
Buick	Park Avenue	2005	Chrysler	Sebring	2010
Buick	Rainier	2007	Chrysler	Town & Country	2016
Buick	Rendezvous	2007	Dodge	Avenger	2014
Buick	Terraza	2007	Dodge	Caliber	2012
Buick	Verano	2017	Dodge	Dakota	2011
Cadillac	ATS	2019	Dodge	Dart	2016
Cadillac	CTS	2019	Dodge	Intrepid	2004
Cadillac	Catera	2001	Dodge	Magnum	2008
Cadillac	DTS	2011	Dodge	Neon	2005
Cadillac	DeVille	2005	Dodge	Nitro	2011
Cadillac	SRX	2016	Dodge	Ram Van	2003
Cadillac	STS	2011	Dodge	Ramcharger	1993
Cadillac	Seville	2004	Dodge	Stratus	2006
Cadillac	XTS	2019	Fiat	500	2019
Chevrolet	Astro	2005	Ford	E150	2014
Chevrolet	Avalanche	2013	Ford	Excursion	2005
Chevrolet	Aveo	2011	Ford	Fiesta	2019
Chevrolet	Cavalier	2005	Ford	Five Hundred	2007
Chevrolet	Cobalt	2010	Ford	Flex	2019

Ford	Focus	2018
Ford	Freestar	2007
Ford	Freestyle	2007
Ford	Taurus	2019
Ford	Thunderbird	2005
Ford	Windstar	2003
GMC	Envoy	2009
GMC	Safari	2005
GMC	Sonoma	2004
Geo	Metro	1997
Geo	Prizm	1997
Geo	Tracker	1997
Honda	Crosstour	2015
Honda	Element	2011
Honda	Prelude	2001
Honda	S2000	2009
Hyundai	Azera	2017
Hyundai	Equus	2016
Hyundai	Genesis	2016
Hyundai	Tiburon	2008
Hyundai	Veracruz	2012
Infiniti	EX35	2012
Infiniti	EX37	2013
Infiniti	FX35	2012
Infiniti	FX37	2013
Infiniti	G20	2002
Infiniti	G25	2012
Infiniti	G35	2008
Infiniti	G37	2013
Infiniti	I30	2001
Infiniti	I35	2004
Infiniti	M35	2010
Infiniti	M37	2013
Infiniti	M45	2010
Infiniti	Q40	2015
Infiniti	Q70	2019
Infiniti	QX30	2019
Infiniti	QX56	2013
Infiniti	QX70	2017
Isuzu	Ascender	2008
Isuzu	Axiom	2004
Isuzu	Rodeo	2004
Isuzu	Trooper	2002
Isuzu	VehiCROSS	2001
Jaguar	XJ12	1996
Jaguar	XJ6	1997
Jaguar	XJ8	2009
Jeep	Commander	2010
Jeep	Liberty	2012
Jeep	Patriot	2017
Kia	Amanti	2009
Kia	Borrego	2009
Kia	Rondo	2010
Kia	Sephia	2001
Kia	Spectra	2009
Lexus	ES 300	2003
Lexus	ES 330	2006
Lexus	GS 300	2019
Lexus	GX 470	2009
Lexus	IS 250	2015
Lexus	LS 430	2006
Lexus	LS 460	2017
Lexus	RX 300	2003
Lexus	RX 330	2006
Lincoln	LS	2006
Lincoln	MKC	2019
Lincoln	MKS	2016
Lincoln	MKT	2019
Lincoln	MKX	2018
Lincoln	Mark LT	2008
Lincoln	Town Car	2011
Lincoln	Zephyr	2006
Mazda	626	2002
Mazda	CX-7	2012
Mazda	MPV	2006
Mazda	Millenia	2002
Mazda	Protege	2003
Mazda	Tribute	2011
Mercury	Cougar	2002
Mercury	Grand Marquis	2011
Mercury	Mariner	2011
Mercury	Milan	2011
Mercury	Montego	2007
Mercury	Monterey	2007
Mercury	Mountaineer	2010
Mercury	Sable	2009
Mercury	Villager	2002

Mitsubishi	Eclipse	2012	Volvo	C30	2013
Mitsubishi	Endeavor	2011	Volvo	C70	2013
Mitsubishi	Galant	2012	Volvo	S40	2011
Mitsubishi	Lancer	2017	Volvo	S80	2016
Mitsubishi	Montero	2006	Volvo	V40	2004
Mitsubishi	Montero Sport	2004	Volvo	V50	2011
Mitsubishi	Raider	2009	Volvo	V70	2010
Nissan	Cube	2014			
Nissan	Juke	2017			
Nissan	Xterra	2015			
Saab	9-7X	2009			
Saturn	Aura	2009			
Saturn	LS	2010			
Saturn	Outlook	2010			
Saturn	Relay	2007			
Saturn	SC	2002			
Saturn	SL	2002			
Saturn	Sky	2009			
Scion	FR-S	2016			
Scion	iA	2016			
Scion	iM	2016			
Scion	iQ	2015			
Subaru	B9 Tribeca	2007			
Subaru	Baja	2006			
Suzuki	Aerio	2007			
Suzuki	Forenza	2008			
Suzuki	Grand Vitara	2013			
Suzuki	Kizashi	2013			
Suzuki	Reno	2008			
Suzuki	SX4	2013			
Suzuki	Verona	2006			
Toyota	Camry Solara	2008			
Toyota	Celica	2005			
Toyota	Corolla iM	2018			
Toyota	FJ Cruiser	2014			
Toyota	MR2	2005			
Toyota	Matrix	2013			
Volkswagen	Beetle	2019			
Volkswagen	CC	2017			
Volkswagen	Cabrio	2002			
Volkswagen	Eos	2016			
Volkswagen	GTI	2014			
Volkswagen	Rabbit	2009			
Volkswagen	Touareg	2017			

Table B.4: **Discontinuation of Makes.** This table reports the discontinuation dates for US automotive brands since 1995. All dates are from Factiva and represent the press release date.

Brand	**Parent**	**Discontinuation**
Geo	General Motors	December 1997
Eagle	Chrysler	September 1998
Plymouth	Daimler-Chrysler	June 2001
Oldsmobile	General Motors	April 2004
Saturn	General Motors	October 2010
Pontiac	General Motors	October 2010
Mercury	Ford	January 2011
Saab	Saab	December 2011

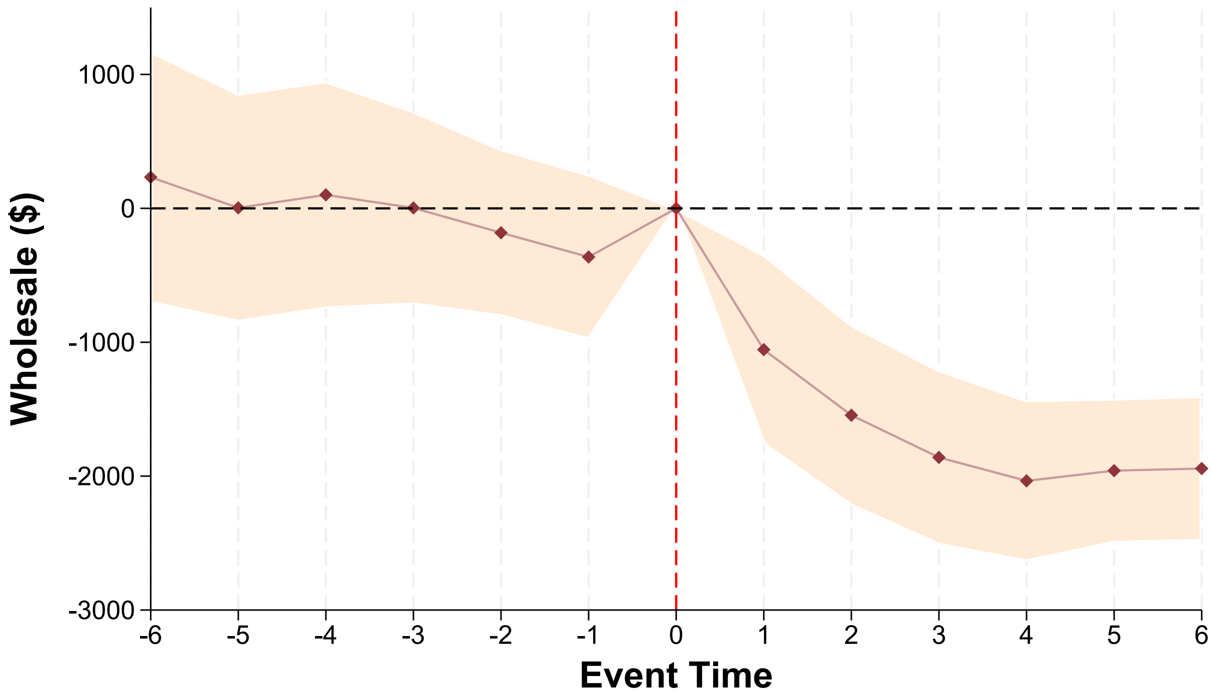

Figure B.2: **Change in Wholesale Value against Event Time.** This figure presents differences in the wholesale value across vehicles (models & makes) that were discontinued and those that were not. The plot displays the regression coefficients for timing indicators around the year the model was discontinued (discontinuation year=0). The dependent variable is the average annual wholesale value of the vehicle as reported by Black Book. Included fixed effects are Make/Model x Vintage Year and Contract Year x Parent Company.

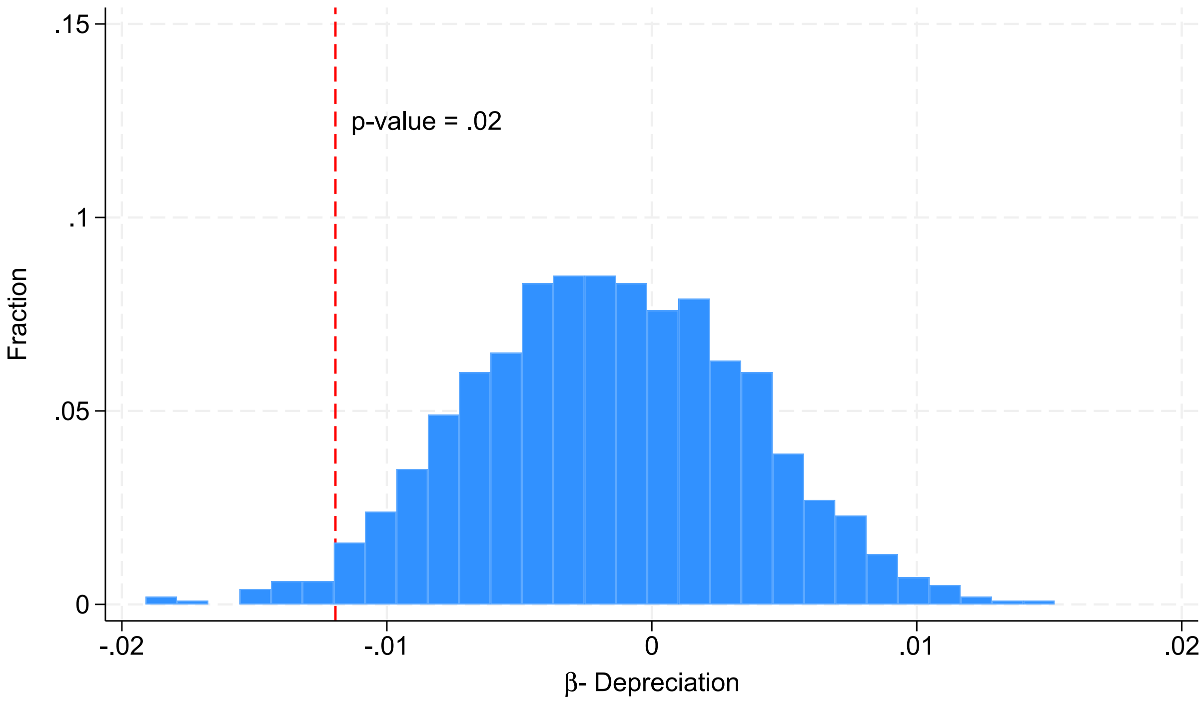

Figure B.3: **Permutation Test – Blackbook.** This figure presents the results from running a permutation test of the YoY depreciation results. Specifically, among vehicles that are never discontinued we randomly assign a discontinuation year to makes and models such that discontinuations approximately match the discontinuation years observed in our sample. We then run a regression of the YoY depreciation on the placebo Model Discontinuation indicator, analogous to column (1) of Table 2. We repeat this simulation 1,000 and plot the distribution of the placebo coefficients relative to the coefficient in column (1) of Table 2. The p-value represents the percent of observations in the distribution of placebo coefficients that exceed the observed coefficient.

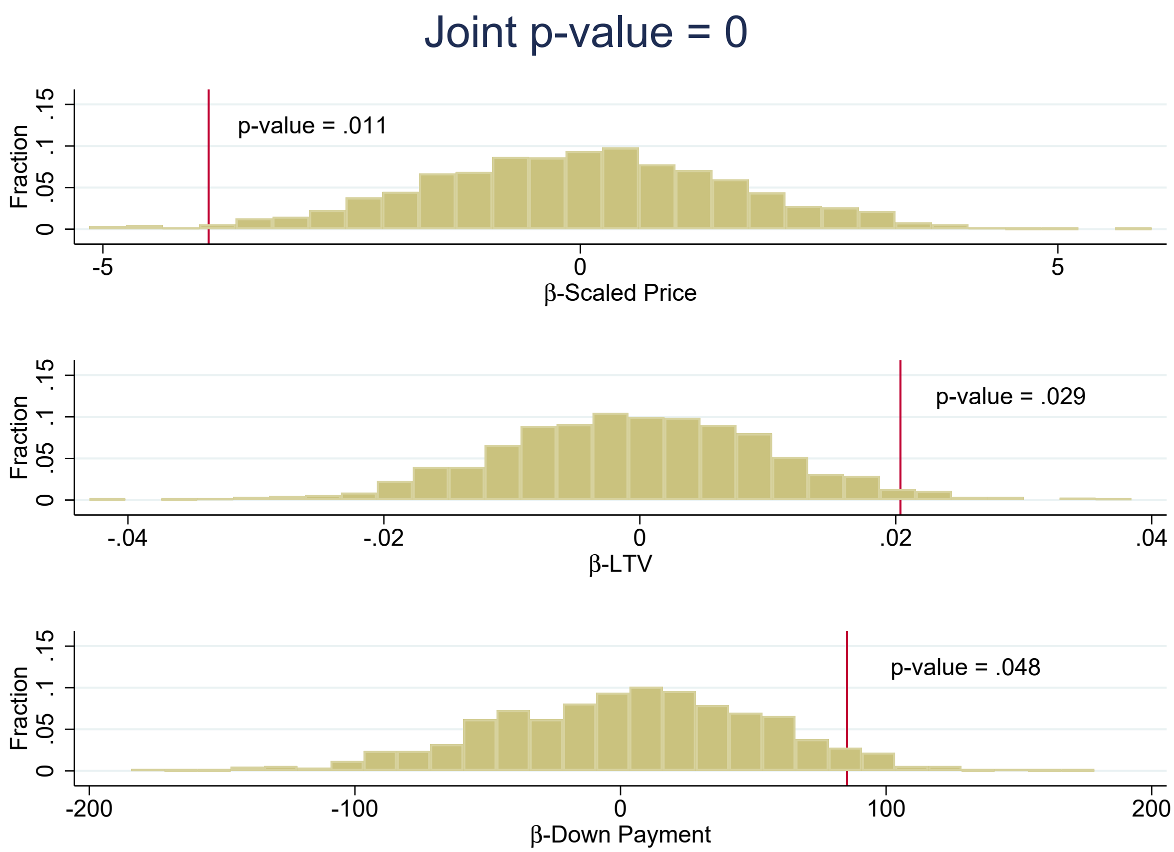

Figure B.4: **Permutation Test – Loan.** This figure presents the results from running a permutation test of the Scaled Price, Down Payment, and LTV results. Specifically, among vehicles that are never discontinued we randomly assign a discontinuation year to makes and models such that discontinuations approximately match the discontinuation years observed in our sample. We then run a regression of the Scaled Price, Down Payment, and LTV on the placebo Model Discontinuation indicator, analogous to column (4) of Table 3, and column (1) of Table 7 and Table 8, respectively. We repeat this simulation 1,000 and plot the distribution of the placebo coefficients relative to the coefficient in column (4) of Table 3, and column (1) of Table 7 and Table 8, respectively. The p-value represents the percent of observations in the distribution of placebo coefficients that exceed the observed coefficient. The joint p-value is the percent of observations for which the placebo coefficients across all three specifications jointly exceed the observed coefficients.

Table B.5: **Amount Financed relative to Asset-Based Securitization.** This table reports estimates from panel regressions of the amount financed. In columns odd numbered columns, the dependent variable is the amount financed by the borrower. In even numbered columns, the dependent variable is the log of the amount financed. *Eq/Total* is the dollar value of securitization of equipment loans over the total of credit card, student, and equipment loan securitization. *Q2 Income*, *Q3 Income*, *Q4 Income* are indicators for the 2nd, 3rd, and 4th quartiles of income for the borrower in the vehicle purchase year. *Log Income* is the log of the monthly borrower income. *Post-Crisis* is an indicator =1 if the transaction took place after 2010. The sample period begins in 2003. Robust standard errors are clustered by transaction year. The t-statistics are shown in parentheses below the coefficient estimates. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Post-2007		Full-Sample		Post-2007		Full Sample	
	Amt. Fin.	Log(Amt. Fin.)	Amt. Fin.	Log(Amt. Fin.)	Amt. Fin.	Log(Amt. Fin.)	Amt. Fin.	Log(Amt. Fin.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Q2 Income	882.89***	0.05***	986.83***	0.06***				
	(8.38)	(5.76)	(11.23)	(8.05)				
Q3 Income	1149.31***	0.06***	1442.24***	0.08***				
	(7.08)	(5.18)	(12.67)	(9.37)				
Q4 Income	1377.68***	0.07***	1834.26***	0.10***				
	(7.25)	(5.02)	(14.65)	(9.06)				
Q2 Income x EQ/Total	1103.04**	0.11***	978.74	0.10**				
	(2.77)	(3.32)	(1.67)	(2.18)				
Q3 Income x EQ/Total	2440.84***	0.18***	2331.01**	0.17**				
	(3.70)	(3.92)	(2.38)	(2.71)				
Q4 Income x EQ/Total	2796.49***	0.19***	2882.08**	0.20**				
	(3.82)	(3.79)	(2.55)	(2.85)				
Post-Crisis x Q2 Income			-61.23	-0.01				
			(-0.48)	(-1.21)				
Post-Crisis x Q3 Income			-260.82	-0.02				
			(-1.13)	(-1.62)				
Post-Crisis x Q4 Income			-493.43	-0.04*				
			(-1.65)	(-2.01)				
Log Income					1342.06***	0.06***	2011.61***	0.11***
					(5.57)	(3.66)	(16.71)	(9.74)
Log Income x EQ / Total					3060.37***	0.22***	3526.45***	0.25***
					(3.64)	(3.93)	(3.25)	(3.85)
Post-Crisis x Log Income							-839.19**	-0.06***
							(-2.69)	(-3.07)
Vehicle Model x Vintage FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dealer FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Parent x Contract Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	228638	228638	290420	290420	228638	228638	290420	290420
Adjusted R^2	0.69	0.69	0.71	0.71	0.69	0.69	0.71	0.71

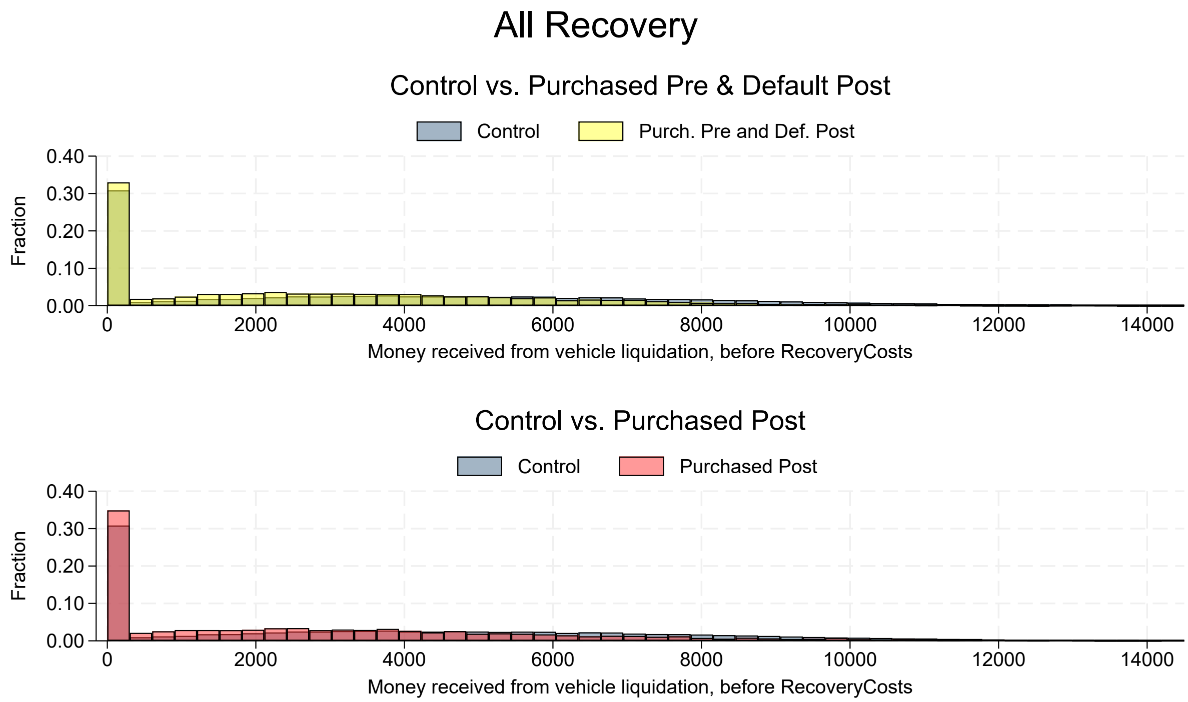

Figure B.5: **Gross Default Recovery (All Recoveries) Conditional on Purchase Timing.** This figure presents of the gross recovered vehicle value conditional on the timing of the purchase. The top panel compares the gross dollar vehicle recovery on loans of vehicles purchase discontinuation but defaulted after discontinuation, and the bottom panel compares the gross dollar vehicle recovery on loans of vehicles purchased post-discontinuation. The control group is both vehicles that were not ever discontinued and vehicles that were purchased within 2-years prior to vehicle discontinuation but defaulted before discontinuation.