Identifying the Depreciation Rate of Durables from Marginal Spending Responses*

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Abstract

This paper presents a new method to estimate the depreciation rate of durable goods using a combination of identified marginal and average spending shares. We apply our method to Chinese spending responses to disposable income changes induced by monetary policy in 2008-2009. The marginal total spending response (MPX) is 0.40. About 46% of this marginal spending response is due to durable goods. By combining this marginal spending share on durables with an average spending share of 14%, we estimate the annual depreciation rate of durables in China to be 0.17.

Keywords: Consumption, Durables, Monetary Policy
JEL Classification: E21, E52

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1 Introduction

Several authors argue that spending on durable goods plays an important role in explaining business cycle dynamics and the transmission of economic policies. For example, Berger and Vavra (2015) show that durable spending and thus aggregate demand is less responsive to income shocks during recessions. Similarly, Barsky, House, and Kimball (2007) argue that combinations of the relative stickiness of prices and the depreciation rate of durable goods crucially matter for aggregate transmission of monetary policy in sticky-price models. Importantly, these results depend on the depreciation rate of durable goods.

The existing method to compute depreciation rates on durable goods relies on using changes in the price of that good with age (see, e.g., Hulten and Wykoff, 1981a,b; Fraumeni, 1997). This method works well for durable goods with an established vintage market, such as houses or cars. However, it is not applicable for broader sets of durable goods, such as furniture and household appliances, for which the vintage market is either missing or very thin. Instead, the estimation of depreciation rates for these goods often relies on strong assumptions or even best-guesses (Fraumeni, 1997).

This paper presents a new method to identify the depreciation rate of durable goods from marginal spending responses. Our starting point is a standard consumption-saving model with preferences over non-durable and durable consumption goods. We use the model to show how to identify the depreciation rate of durables using a combination of marginal and average spending shares. Intuitively, when disposable income increases, the household increases non-durable and durable goods consumption. But to raise durable goods consumption, the household must increase the stock of durables. Spending on durables therefore jumps on impact, captured in the marginal spending shares. Because the size of this jump in spending share depends on the depreciation rate of durables, we are able to estimate the depreciation rate using a combination of average and marginal spending shares. Importantly, our approach does not rely on observing prices by age in vintage markets but instead identifies the depreciation rate from the revealed behavior of household spending in response to income changes. Our approach therefore directly estimates the relevant depreciation rate on the durable goods that households purchase.

We illustrate our method using data on how Chinese households adjust their spending to disposable income changes induced by monetary policy. More specifically, we focus on five cuts in the monetary policy rate introduced by the People's Bank of China (PBoC) during the fall of 2008 as a response to the global financial crisis. These policy rate cuts led to a fall of 216 basis points in the one-year benchmark loan rate. The Chinese mortgage

markets' so-called semi-floating rate institutional framework implies that mortgage rates move with the monetary policy rate changes but are adjusted only once a year. As a result, the total change in the monetary policy rate during Fall 2008 resulted in one large mortgage rate reduction on January 1st, 2009. It then stayed constant throughout 2009. We combine this considerable interest rate reduction with detailed data on Chinese households' income and spending from the Urban Household Survey to estimate spending responses. Our identification follows a Bartik design: we instrument the change in disposable income by households' predetermined mortgage debt exposure interacted with the interest rate change. Hence, we identify a cash-flow channel of monetary policy by comparing the consumption response of households with high debt exposure to those with low debt exposure.

To estimate the depreciation rate using our model, our approach requires estimates of the households' spending response to the change in disposable income and how this spending response is allocated between durables and non-durables. We find that households increase spending on total consumption when interest costs fall due to lower mortgage rates. Our evidence thus provides support for the importance of the cash-flow channel in aggregate monetary transmission emphasized in the literature.[1] We estimate an implied marginal propensity to spend of 0.40 (s.e = 0.20), similar to Agarwal, Deng, Gu, He, Qian, and Ren (2022) who investigate the same mortgage rate reduction using credit card spending data. This spending response is large compared with standard models of household behavior (e.g., the permanent income hypothesis) but comparable in size to the literature on marginal spending responses to unanticipated transitory income changes.[2]

We find further that durables, defined as vehicles, household appliances, and furniture, account for 46% of the marginal spending response while 54% is due to spending on non-durables. The marginal spending response is thus primarily driven by spending on non-durables. This finding is important for the literature relying on imputed consumption spending from administrative data on income and wealth (see, e.g., Fagereng et al., 2021, Baker, Kueng, Meyer, and Pagel, 2022). Since imputed consumption is constructed as income not saved, it is not possible to say what type of goods or services they acquire. One suggested way of squaring the high marginal spending responses in the empirical literature with standard consumption models is to claim that a large share of the spending

[1] See for example Holm, Paul, and Tischbirek (2021), Flodén, Kilström, Sigurdsson, and Vestman (2020), Jappelli and Scognamiglio (2018), Di Maggio, Kermani, Keys, Piskorski, Ramcharan, Seru, and Yao (2017), and La Cava, Hughson, and Kaplan (2016).

[2] See, e.g., Fagereng, Holm, and Natvik (2021) and Golosov, Graber, Mogstad, and Novgorodsky (2021) for spending responses to lottery prizes, and Johnson, Parker, and Souleles (2006) and Parker, Souleles, Johnson, and McClelland (2013) for spending responses to tax rebates.

response is due to durables.[3] Our findings only partially support such an interpretation since a large part of the marginal spending is still due to non-durables.[4]

Based on the above estimates, we achieve our main empirical contribution: estimating the depreciation rate of durable goods in China. We estimate the annual depreciation rate to be 0.17 (s.e. 0.10) by combining a marginal spending share on durables of 46% with an average spending share of 14%. We argue that our estimated depreciation rate can be used to calibrate models of household behavior applied to China.

Our estimated depreciation rate is somewhat higher than what studies using similar definitions of durables compute from U.S. data. For example, Harmenberg and Öberg (2021) calibrate their depreciation rate using cars, furniture, and appliances, and compute a *quarterly* depreciation rate of 0.023 using U.S. data.[5] An alternative method is to impute the depreciation rate in China by combining spending shares from Chinese data with depreciation rates on durable categories from the Bureau of Economic Analysis. This alternative method results in an annual depreciation rate of 0.16, similar to our benchmark estimate of 0.17. Comparably, by using the same durable categories in the U.S., we also get a depreciation rate of 0.16. Hence, our results suggest that the depreciation rate is relatively similar in the U.S. and China. Moreover, imputing the depreciation rate in China by combining spending shares in China with the depreciation rate of durable categories from the U.S. seems to work reasonably well.

The rest of the paper proceeds as follows. Section 2 presents a non-durable and durable spending model and shows how to use this model to identify the depreciation rate of durable goods. Section 3 describes the institutional setting and the data. Section 4 lays out our empirical strategy. Section 5 presents our main results. Section 6 concludes.

[3]See, e.g., the mapping from spending responses to consumption responses in Laibson, Maxted, and Moll (2021). Tauber and Van Zandweghe (2021) also discuss the overproportional spending on durables during the Covid-pandemics.

[4]Tracey and Van Horen (2021) examine the consumption effects of changes in required downpayments in the U.K. They also highlight the role of non-durables in the spending response to changes in mortgage-related shifts in disposable income. They find that spending on non-durables represents a larger share of the spending response. Their study, just as ours, enriches the findings of Di Maggio et al. (2017) which exclusively focus on how changes in mortgage expenses affect durable spending (spending on cars, in particular).

[5]Similarly, Bils and Klenow (1998) also use comparable depreciation rates for similar goods, and Browning and Crossley (2009) employ an even higher annual rate of depreciation of 0.34 in a sample that also includes less durable goods such as clothing. Papers that include housing as part of durable consumption use lower depreciation rates. For example, Berger and Vavra (2015) and Zorzi (2020) use a quarterly depreciation rate of 0.018, and McKay and Wieland (2021) use an annual depreciation rate of 0.068. The three papers are calibrated to the Bureau of Economic Analysis's definition of fixed assets, which includes housing. Similarly, Sterk and Tenreyro (2018) use an annual depreciation rate of 0.04. Their estimate is taken from Baxter (1996) who adjust Bernanke (1985)'s high (22%) annual depreciation rate for housing.

2 Identifying the Depreciation Rate of Durables

This section presents a standard consumption-saving model with preferences over durable and non-durable consumption. The main theoretical result is to map average and marginal spending shares to the depreciation rate of durable goods.

The model. Households maximize their discounted flow of utility from consumption

$$\max_{\{c_{n,t},c_{d,t}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U\left(\overbrace{\left(\alpha^{1/\varepsilon} c_{n,t}^{\frac{\varepsilon-1}{\varepsilon}} + (1-\alpha)^{1/\varepsilon} c_{d,t}^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}}}^{C_t}\right)$$

subject to

$$\begin{aligned} b_{t+1} &= w_t + (1+i_t)b_t - c_{n,t} - p_{d,t}I_t \\ c_{d,t+1} &= (1-\delta)c_{d,t} + I_t \\ p_{d,t+1} &= (1+g)p_{d,t} \end{aligned}$$

where $c_{n,t}$ is non-durable consumption, $c_{d,t}$ is durable consumption, b_t is a one-period bond, w_t is the wage, I_t is the purchase of durable goods, $p_{d,t}$ is the price of durable goods (relative to non-durable goods), i_t is the interest rate, δ is the depreciation rate of the durable good, α is the weight on non-durable consumption, ε is the elasticity of substitution between non-durable and durable goods, g is the trend growth rate in the relative price of durables, and β is the discount factor. To solve the model, we redefine wealth as $a_t = b_t + p_{d,t}c_{d,t}$. The budget constraint is then

$$a_{t+1} = w_t + (1+i_t)a_t - c_{n,t} - \underbrace{p_{d,t}(i_t + \delta - g)}_{\hat{p}_{d,t}} c_{d,t} \tag{1}$$

where one can now think of the durable consumption good like a non-durable good with the price $\hat{p}_{d,t} := p_{d,t}(i_t + \delta - g)$. Intuitively, $i_t + \delta - g$ is the user cost of durables, so $\hat{p}_{d,t}$ is the implicit rental price. If $\delta < 1 - i_t$, the relevant price $\hat{p}_{d,t}$ is lower than the price you pay per unit $p_{d,t}$ since durable goods last many time periods. Importantly, $\hat{p}_{d,t}$ is the relevant price when allocating spending between non-durables and durables.

The demand for non-durable and durable goods are

$$c_{n,t} = \alpha\left(\frac{1}{P_t}\right)^{-\varepsilon} C_t, \qquad c_{d,t} = (1-\alpha)\left(\frac{\hat{p}_{d,t}}{P_t}\right)^{-\varepsilon} C_t$$

where $P_t = \left(\alpha + (1-\alpha)\hat{p}_{d,t}^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}$ is the aggregate price index and the model-consistent spending shares are

$$\chi_{n,t} = \frac{c_{n,t}}{P_t C_t} = \alpha\left(\frac{1}{P_t}\right)^{1-\varepsilon}, \qquad \chi_{d,t} = \frac{\hat{p}_{d,t}c_{d,t}}{P_t C_t} = (1-\alpha)\left(\frac{\hat{p}_{d,t}}{P_t}\right)^{1-\varepsilon}.$$

However, these model-consistent spending shares are generally not observable because they depend on prices not observed. Instead, we will define two alternative spending shares that can be observed in the data: the observable and the marginal spending share.

Proposition 1. *Assume that $\beta(1+i_t)P_{t+1}/P_t = 1$, then the observable spending shares are*

$$\frac{c_{n,t}}{c_{n,t}+p_{d,t}I_t} \approx \frac{\alpha}{\alpha + (\delta - \varepsilon g \chi_{n,t})p_{d,t}^{1-\varepsilon}\frac{1-\alpha}{(i_t+\delta-g)^{\varepsilon}}}, \qquad \frac{p_{d,t}I_t}{c_{n,t}+p_{d,t}I_t} \approx \frac{(\delta - \varepsilon g \chi_{n,t})p_{d,t}^{1-\varepsilon}\frac{1-\alpha}{(i_t+\delta-g)^{\varepsilon}}}{\alpha + (\delta - \varepsilon g \chi_{n,t})p_{d,t}^{1-\varepsilon}\frac{1-\alpha}{(i_t+\delta-g)^{\varepsilon}}}. \quad (2)$$

Appendix A.1 presents the proof. Along the path, investment in durable goods equals the depreciation rate times the stock of durable goods adjusted for the growth rate of relative prices. Intuitively, households must invest the depreciation rate each period to keep the level of durables constant. However, it is adjusted for trend growth because an increase in the relative price of durables ($g > 0$) implies that the spending share on durables will decrease gradually. We next compute the marginal spending shares in response to changes in disposable income.

Proposition 2. *The marginal spending shares are*

$$\frac{dc_{n,t}}{d(c_{n,t}+p_{d,t}I_t)} = \frac{\alpha}{\alpha + p_{d,t}^{1-\varepsilon}\frac{1-\alpha}{(i_t+\delta-g)^{\varepsilon}}}, \qquad \frac{d(p_{d,t}I_t)}{d(c_{n,t}+p_{d,t}I_t)} = \frac{p_{d,t}^{1-\varepsilon}\frac{1-\alpha}{(i_t+\delta-g)^{\varepsilon}}}{\alpha + p_{d,t}^{1-\varepsilon}\frac{1-\alpha}{(i_t+\delta-g)^{\varepsilon}}}. \quad (3)$$

Appendix A.2 presents the proof. Proposition 1 and 2 illustrate how the marginal and average spending shares differ due to the presence of durable goods or trends in relative prices. If the durable goods is non-durable ($\delta = 1$) and there is no trend in relative prices ($g = 0$), the marginal and average spending shares are the same. But since $\delta \neq 1$ and $g \neq 0$, the marginal spending shares differ from the observable spending shares. Intuitively, when disposable income increases, the household adjusts to a higher level of non-durable and durable goods consumption. But when raising durable goods consumption to a new level, the household must increase the stock of durables on impact. Spending on durables therefore jumps on impact and the marginal spending share on durables includes this jump.

Identifying the depreciation rate. The results in Proposition 1 and 2 allow us to compute a measure of the depreciation rate of durables from a combination of marginal and observed spending shares. We define two data moments

$$\hat{m}_1 = \text{observed spending share on non-durables} = \frac{\alpha}{\alpha + (\delta - \varepsilon g \chi_{n,t}) p_{d,t}^{1-\varepsilon} \frac{1-\alpha}{(i_t+\delta-g)^{\varepsilon}}},$$

$$\hat{m}_2 = \text{marginal spending share on non-durables} = \frac{\alpha}{\alpha + p_{d,t}^{1-\varepsilon} \frac{1-\alpha}{(i_t+\delta-g)^{\varepsilon}}}.$$

A direct calculation gives

$$\frac{\frac{1-\hat{m}_1}{\hat{m}_1}}{\frac{1-\hat{m}_2}{\hat{m}_2}} + \varepsilon g \chi_{n,t} = \hat{\delta}. \tag{4}$$

Hence, a combination of marginal and average spending shares allows us to identify the depreciation rate independently of most other model parameters, including the interest rate i, the discount rate β, and the utility weight α. In our benchmark analysis, we follow Ogaki and Reinhart (1998) and assume $\varepsilon = 1$.

How general are these results? Models of durable goods typically include additional components. We discuss three such extensions here. First, durable goods are typically indivisible. For example, cars are considered to be lumpy since households cannot buy an infinitesimal share in a car. We assume that composite durable goods can be bought incrementally. While that may seem an unreasonable assumption in a single market (such as for a car), it is more realistic when considering all durable goods jointly. For example, it is straightforward to show theoretically that with infinitely many indivisible durable goods, the composite durable good is divisible. The underlying argument is therefore that we are in a situation where durable goods consumption consists of sufficiently many potentially indivisible durable goods.

Second, many (secondary) durable goods markets are thin, which gives rise to partial irreversibility because the second-hand price is (much) lower than the purchase value. Models of durables often include a re-sale wedge to account for partial irreversibility. The re-sale wedge is important when considering risk, for example income or unemployment risk, because it reduces the insurance value of durable goods. A re-sale wedge is indeed crucial to capture the observed pattern that durable goods consumption falls more in recessions. However, without risk, the re-sale wedge is irrelevant because households never sell durable goods. We therefore do not include a re-sale wedge in the model.

Third, models of durable goods often consider adjustment costs. For example, housing transactions often entail large moving costs. In our model, we assume that durable

goods have no adjustment costs, which is a reasonable simplifying assumption in the Chinese setting where durable goods consist of goods with relatively low adjustment costs (vehicles, household appliances, and furniture). Away from the Chinese special case, our assumptions are realistic as long as one focuses on easily adjustable durable goods. This could be particularly the case for studies on post-covid consumption recovery where durable goods consumption is viewed as a substitute for consumption of services (Tauber and Van Zandweghe, 2021). But in other settings where goods are indivisible or there are substantial adjustment costs, for example in settings where housing is important, our method may be less applicable.

The rest of this paper applies the approach described above to estimate average and marginal spending shares and identify the depreciation rate of durable goods using Chinese household consumer survey data.

3 Background and Data

This section describes the institutional framework for monetary policy and debt contracts in China, provides some background on how the financial crisis affected China, and presents the data and summary statistics.

3.1 Institutional Framework

According to the Law of the People's Republic of China on the People's Bank of China (PBoC), the central bank "shall, under the leadership of the State Council, formulate and implement monetary policy." The aim of monetary policy is "[...] to maintain the stability of the value of the currency and thereby promote economic growth." The PBoC uses M2 growth as its intermediate target for monetary policy (Chen, Ren, and Zha, 2018). The PBoC adopts a set of quantity-based and price-based instruments to achieve its target, including open market operations, reserve ratios, liquidity support, and benchmark interest rates.[6] Chinese economic policy is formulated such that it is the annual assembly makes the annual target for GDP growth of the National People's Congress (NPC). Each year, the People's Bank of China reports its decisions on the annual money supply, interest rates, and foreign exchange rates to the State Council to receive approval from the NPC.

During the run-up to the 2007-2009 global financial crisis, China was initially largely unscathed. Contrary to most major economies, the PBoC increased its key policy rate

[6]Since the mid-2010s, the PBoC started to use more market-based tools to manage liquidity in the banking system, such as repo/reversed repo, medium-term lending facility (MLF), and standing lending facility (SLF), to ensure a tighter control on market interest rates.

six times in 2007 to fight inflation. However, as the subprime crisis became a global financial crisis after the collapse of Lehman Brothers in September 2008, in response to a slowdown of the growth of the Chinese economy and in order to avoid large interest rate differentials to the rest of the world,[7] the PBoC swiftly made five aggressive cuts in the key policy rate within 14 weeks before the end of 2008. Table 1 illustrates that these policy rate cuts resulted in a 216 basis points reduction in the one-year benchmark loan rate or 189 basis points in the mid-to-long-term benchmark loan rate. These reductions are the largest ones introduced by the PBoC in a single year since the Asian financial crisis in 1997. The monetary policy expansion together with aggressive fiscal stimulus resulted in the Chinese economy staying more or less stable during 2008 and 2009 with GDP growth rates at 9.7 and 9.4 percent (World Bank), respectively. The PBoC eventually raised the interest rates in October 2010.

Dates	One-year	Δ One-year	>5-year	Δ >5-year
September 16, 2008	7.20%	-27bps	7.74%	-9bps
October 8, 2008	6.93%	-27bps	7.47%	-27bps
October 30, 2008	6.66%	-27bps	7.20%	-27bps
November 27, 2008	5.58%	-108bps	6.12%	-108bps
December 23, 2008	5.31%	-27bps	5.94%	-18bps
Total Δ		-216bps		-189bps

Table 1: Cuts in PBoC benchmark loan rates, 2008

Unlike in the U.S. or Europe, where household loans typically have a fixed or adjustable rate, banks in China mainly offer only one type of loan: a loan with a semi-floating rate. The loan rate of Chinese households is determined when a loan application is approved and is equal to the PBoC's benchmark loan rate plus a borrower-specific risk premium; refinancing is almost non-existent. The mortgage rate is adjusted to any changes in the benchmark loan rate only on January 1st each year. The yearly adjustment reflects the cumulated policy rate changes during the past year. The uniform, simultaneous, and

[7] See the announcement from the Central People's Government of the People's Republic of China, http://www.gov.cn/ztzl/kdnx/content_1184992.htm.

substantial rate adjustment on household debt on January 1st, 2009, provides us with a plausibly exogenous (due to the fact that, as discussed above, it was mostly a reaction to global economic dynamics) and large reduction in interest cost changes that affect all households simultaneously, allowing us to identify the effects of expansionary monetary policy on household consumption.

3.2 Data

To examine the households' consumption response to the changes in disposable income induced by the monetary policy shift, we use annual data from China's Urban Household Survey (UHS).[8] The UHS covers most provincial regions in China based on stratified random sampling and has been used extensively in research.[9] The households included in the survey record detailed breakdowns of spending and income. The survey also contains information on household characteristics such as age, education, and the number of household members.

Sample selection. We start by restricting our sample to include only households included in both the 2008 and 2009 waves of the UHS.[10] Since our identification relies on comparing households with different levels of mortgage debt, we focus only on households with mortgages (5% of households). Because we only observe flow expenses related to mortgages, we drop the top and bottom 1% in the distribution of changes in mortgage expenses since these households likely adjusted their debt levels. We also drop outlying observations in gross income (top and bottom 1%), observations with negative disposable income, and observations with very high mortgage expenses to gross income (top 1%). Further, since health expenses typically are related to adverse events that affect households severely, we drop households with very high health expenses (top 1%). We also exclude households with equity and households receiving income from their own business since they are more directly exposed to the financial crisis. After imposing these restrictions, our sample consists of 1,236 unique households (4% of the total sample).

[8] See Fang, Wailes, and Cramer (1998) for an overview of the UHS.

[9] See, e.g., Han, Liu, and Zhang (2012), Chamon, Liu, and Prasad (2013), Edlund, Li, Yi, and Zhang (2013), Anderson, Farcomeni, Pittau, and Zelli (2016), and Ge, Yang, and Zhang (2018) for recent examples.

[10] Households participate in the survey in a rotating panel data manner. One-third of households are replaced each year with new entrants. Hence, each household should stay in the survey for three years. However, a change in the questionnaire and in the sampling methodology starting from 2008 imply that most households participating in the 2007 edition were not covered by the 2008 survey. As our method requires observing a sufficient number of households with non-zero mortgage-debt levels in two consecutive years data availability prior to 2008 is limited but it is sufficient for the 2008-2009 period that we are interested in observing.

	Mean	S.D.	P10	P50	P90
Panel A: Household Characteristics					
Age	43.23	11.23	30	41	59
Household members	2.98	0.84	2	3	4
Panel B: Income and Spending					
Gross income	65,681	32,503	32,630	57,653	108,335
Loan payment (interest + amortization)	13,843	10,820	3,600	11,012	27,463
Disposable income	51,838	28,629	23,604	45,040	89,141
Total spending	38,771	30,631	16,218	30,991	67,527
Non-durables	31,449	20,945	13,951	26,083	55,171
Durables	7,322	15,165	723	3,441	13,432
Panel C: Shares					
Non-durables to total spending	0.855	0.123	0.701	0.889	0.966
Durables to total spending	0.145	0.123	0.034	0.111	0.299
Loan payment to gross income	0.218	0.136	0.064	0.193	0.412

Table 2: Summary Statistics (N = 1,236) in 2008. Values are in RMB (RMB/USD $\approx$ 7.7 in 2008). Age is the age of the household head.

Variable definitions and summary statistics. The outcome variables in our study are total, non-durable, and durable goods spending. We define *total spending* to be the sum of spending on non-durables and durables.[11] Non-durable spending includes food, clothing, articles for daily use, cultural and recreational activities, books and magazines, medicine, and fuel. Durable spending includes vehicles (e.g., cars, motorcycles, and bicycles), household appliances (e.g., washing machines, showers, refrigerators, and TV sets), and furniture. We define *disposable income* as the sum of wages, other income, and transfer income (all net of taxes), net of mortgage expenses (interests and amortization). We define *debt exposure* as mortgage expenses as a share of gross income.

Table 2 presents the summary statistics for the main variables included in our analysis. Households spend on average RMB 38,771 (USD 5,035) per capita on consumption. Around 86% of this total consumption spending is spent on non-durables while the remaining 14% is spent on durables.

[11] Implicitly, we exclude two spending categories (health and education) from total spending.

4 Empirical Setup

To identify the effects of income changes induced by monetary policy on consumption spending, we estimate the following equation

$$\frac{C_{i,t} - C_{i,t-1}}{Y_{i,t-1}} = \beta_0 + \beta_1 \frac{Y_{i,t} - Y_{i,t-1}}{Y_{i,t-1}} + \beta_2 \mathbf{X}_{i,t-1} + \alpha_p + u_{i,t} \tag{5}$$

where $C_{i,t}$ is spending on either total, non-durable, or durable consumption goods, $Y_{i,t}$ is disposable income, $\mathbf{X}_{i,t-1}$ is a set of predetermined controls, and α_p captures province-fixed effects. Note that since our data only contains two years, we have only one observation of the consumption change per household. Hence, household and time-fixed effects cannot be employed. To account for unobserved heterogeneity across provinces, we cluster our standard errors at the province level (Abadie, Athey, Imbens, and Wooldridge, 2022).

Importantly, $\frac{Y_{i,t}-Y_{i,t-1}}{Y_{i,t-1}}$ is endogenous as it may be affected by consumption and by potential confounders. We therefore rely on an instrumental variable setup in which we instrument $\frac{Y_{i,t}-Y_{i,t-1}}{Y_{i,t-1}}$ with household i's exposure to debt (mortgage expenses as a share of gross income) in year $t-1$. This setup essentially follows a Bartik identification scheme. In the context of this scheme, our underlying identifying assumption is related to the exogeneity of household debt exposure (this is analogous to the industry shares in the classical Bartik setup described by Goldsmith-Pinkham, Sorkin, and Swift, 2020). There are three necessary assumptions that are important for our identification. First, debt exposure has to affect disposable income. Second, debt exposure has to affect consumption changes only through disposable income. Third, no confounding variables affect both debt exposure and consumption growth. We discuss each of these three assumptions below.

Starting with the first assumption, we show in Table 3 that debt exposure does affect households' disposable income growth. The effect is sizeable and significant, with an F-statistics of 59.23 in the benchmark specification (5).[12]

Concerning the second assumption, our identification assumes that debt exposure affects consumption only through its effect on disposable income. One potential issue with this specification might arise if debt exposure is correlated with housing wealth and, therefore, affects consumption also via housing wealth effects induced by monetary policy. To address this issue, we first note that house price growth in China was approximately

[12] We also explored two other monetary policy episodes: the interest rate reduction of 0.45 percentage points in February 2002 and the interest rate increase in 0.27 percentage points in October 2004. Both these episodes are similar to the 2008 episode we study because there were no changes in the interest rate in 2003 and 2005. However, the first-stage regressions are not sufficiently precise in these two episodes because the samples of households holding mortgages were small (337 in 2002 and 414 in 2004) and the interest rate changes were relatively modest.

1% in 2009.[13] In addition, we include the change in housing wealth as a share of disposable income as a control variable in our benchmark specification.

A second concern is that our sample period includes a period of global recession (even though, as mentioned above, the Chinese economy was still growing by 9.7 and 9.4 percent in 2008 and 2009, respectively). This could be a problem if the global recession's impact on households is correlated with debt exposure. To reduce this concern, we control for factors correlated with business cycle exposure (age, sector, and province). Moreover, we exclude households with stock market wealth from our sample for the same reason.

A third concern is that the interest rate changes were announced in the fall of 2008 so that households could potentially adjust their debt levels to the lower future interest rates before the mortgage rate changes became effective in 2009. However, most debt consists of mortgages linked to housing and is determined prior to 2008. Furthermore, the aggregate debt level did not move much in the fourth quarter of 2008, suggesting no systematic debt accumulation pattern in late 2008. However, to reduce the concern for mortgage adjustments affecting our results, we drop households with large changes in mortgage expenses from 2008 to 2009. Our sample thus consists of households with relatively stable loan payments (and thus debt levels) in 2008 and 2009.

Finally, to address the third identifying assumption regarding the potential confounders in the analysis, we control for multiple observable variables that potentially affect both debt exposure and consumption growth. Specifically, we control for a second-order polynomial in age, an indicator for whether the household works in the private sector, household size, and a complete set of education and province dummies.

5 Results

This section presents the main results on how monetary policy changes affect household consumption spending. Table 3 presents our main empirical results. We highlight three findings: the estimated total spending response, the marginal spending shares, and the estimated depreciation rate.

Our first finding is that the total spending responses are large, suggesting that the cash-flow channel of monetary policy is important. About 40% of the change in disposable income induced by the interest rate change is spent on consumption. This finding is similar to Agarwal et al. (2022), which also estimate spending responses to the mortgage rate reduction in 2008 using Chinese credit card data. It is also consistent with a literature

[13] We combine data series QCNR628BIS (real house prices) and CHNCPIALLMINMEI (CPI) from FRED to compute the nominal house price growth in China.

	(1)	(2)	(3)	(4)
Panel A: Total Spending				
MPX_{Total}	0.411	0.380	0.439	0.404
	(0.206)	(0.200)	(0.204)	(0.198)
Panel B: Non-durables				
$MPX_{Non-durables}$	0.211	0.206	0.226	0.219
	(0.133)	(0.132)	(0.132)	(0.130)
Marginal Spending $Share_{Non-durables}$	0.514	0.542	0.515	0.544
	(0.129)	(0.139)	(0.104)	(0.114)
Panel C: Durables				
$MPX_{Durables}$	0.200	0.174	0.213	0.184
	(0.097)	(0.094)	(0.088)	(0.087)
Marginal Spending $Share_{Durables}$	0.486	0.458	0.485	0.456
	(0.129)	(0.139)	(0.104)	(0.114)
Panel D: Annual Depreciation Rate of Durables				
$\hat{\delta}$	0.143	0.164	0.143	0.165
	(0.099)	(0.120)	(0.081)	(0.099)
First-stage F-test	87.39	76.92	63.46	59.23
Controls	✗	✗	✓	✓
Province FE	✗	✓	✗	✓
Observations	1,236	1,236	1,236	1,236

Notes: In Panel D, we present estimates of the depreciation rate of durables using equation (4), which requires an adjustment for trend growth in the relative price of durables g and the elasticity of substitution between durable and non-durable goods ε. In these results, we use $g = -0.0427$, $\varepsilon = 1$, and $\chi_{n,t}$ equal to the observable spending share on non-durables (0.86).

Table 3: Marginal propensities to spend out of disposable income changes induced by monetary policy.

that finds significant cash-flow effects of monetary policy (Holm et al., 2021; Flodén et al., 2020; Jappelli and Scognamiglio, 2018; Di Maggio et al., 2017; La Cava et al., 2016) and an extensive literature on estimated spending responses to unanticipated and transitory income movements (Fagereng et al., 2021; Golosov et al., 2021; Parker et al., 2013; Johnson et al., 2006). However, a comparison with this literature should acknowledge that the income movements we are exploring might be interpreted as persistent rather than transitory. In particular, given that the interest rate on mortgages changes only once per year and the interest rate change in 2008 was in response to a global financial crisis, the change should be expected to last somewhat longer than a year.[14]

A potential concern with our estimated marginal spending response is that households could already respond to news about interest rate changes in 2008. Responses to announced interest rate changes will result in a downward bias in our results because our spending response is defined as spending in 2009 minus spending in 2008 as a share of disposable income in 2008. Druedahl, Jensen, and Leth-Petersen (2022) estimate spending response to interest rate announcements in Denmark, finding that liquidity-rich households did respond to news about future interest rate changes. However, the size of these responses to announcements is a mix of expenditure shifting across time and actual increases in spending, making it hard to assess how significant the bias may be in other settings. As we lack higher frequency data on consumption we cannot explicitly address the announcement effect, so we should note that there might be some downward bias in our estimated marginal spending responses.

Our second finding is that around 54% of the total spending response is due to nondurables, while durables make up about 46%. Hence, a large share of the spending response is due to durables. The marginal spending shares differ from the average spending shares in Table 2: households spent 14% of total spending on durables 2008 while 46% of the marginal spending response was due to durables. These relative shares are consistent with the model framework in Section 2 where durables make up a disproportionately large share of marginal spending responses.

The third finding is that the implied annual depreciation rate of durables is 0.17,

[14] It lasted for two years before the rise in mortgage rate on January 1st, 2011, reflecting a cumulated 50 basis-point rise in PBoC's one-year benchmark loan rate during 2010.

computed using (4).[15][16] An annual depreciation rate of 0.17 is higher than typically assumed in models of durable goods calibrated to the U.S. However, comparing our results to papers that use a similar definition of durables is important.[17] Durable goods in the Chinese data are defined as vehicles, household appliances, and furniture, but not housing. Table 4 shows the implied depreciation rate in China using the expenditure weights from the Urban Household Survey and depreciation rates from the Bureau of Economic Analysis (BEA). Our estimated depreciation rate of 0.17 is almost the same as the imputed depreciation rate in China by combining expenditure weights from China with depreciation rates on durable categories from the U.S. Moreover, our estimated depreciation rate is similar to the U.S. depreciation rate using the same durable categories.

6 Conclusion

This paper provides a new method to estimate the depreciation rate of durable goods using a combination of identified marginal and average spending shares. The main advantage of our approach is that we rely on revealed behavior to identify the depreciation rate rather than computing a depreciation rate by weighing together sector-specific depreciation rates using average spending shares. We apply our method to Chinese spending responses to disposable income changes induced by monetary policy in 2008 - 2009. The marginal spending response (MPX) is 0.40, where about 46% of this spending response is due to durable goods. By combining this marginal spending share with an average durable spending share of 14%, we estimate the annual depreciation rate of durables in China to be 0.17. This estimated depreciation rate is similar to the depreciation rate obtained by combining depreciation rates on durable categories from the Bureau of Economic Analysis with expenditure weights from China.

[15] To estimate the depreciation rate, we need to adjust for the model-consistent spending share on non-durables, $\chi_{n,t}$. One issue is that $\chi_{n,t}$ is not observable. However, by noting that

$$\chi_{n,t} = \frac{\alpha}{\alpha + (1-\alpha)\hat{p}_{d,t}^{1-\varepsilon}} \approx \frac{\alpha}{\alpha + (1-\alpha)\hat{p}_{d,t}^{1-\varepsilon}\frac{\delta - \varepsilon g \chi_{n,t}}{r+\delta-g}} = \hat{m}_1,$$

if $r \approx g(1 - \varepsilon\chi_{n,t})$. We use $\hat{m}_1$ (the observed spending share on non-durables) to approximate $\chi_{n,t}$.

[16] To compute the depreciation rate of durables, equation (4) requires an estimate of the trend growth in the relative price of durable goods. We estimate the trend growth in the relative price of durables to be -0.0427 based on the average price growth of durables relative to non-durables from 2002 to 2009 using data from the National Bureau of Statistics in China.

[17] For example, Harmenberg and Öberg (2021) find a quarterly deprecation rate of 0.023 using data on cars, furniture, and appliances, implying an annual depreciation rate of around 0.10. Papers that include housing in durable goods typically use a lower depreciation rate (e.g., Berger and Vavra (2015), Zorzi (2020), and McKay and Wieland (2021) include housing in their definition of durable goods and find a quarterly depreciation rate of 0.018 or an annual depreciation rate of 0.068).

Durables category		Share in total durables consumption 2009		BEA dep. rate
China	U.S.	China	U.S.****	
Autos	Autos	0.0225	0.2625	0.1650*,**
Other vehicles	Other vehicles	0.0262		0.2316
Communication	Communication	0.0762	0.0158	0.1500***
Entertainment	Entertainment	0.2766	0.2346	0.1833
Furniture	Furniture	0.0495	0.1374	0.1179
Household facilities	Household facilities	0.5093	0.0611	0.1500
Watches and jewelry	Watches and jewelry	0.0397	0.0585	0.1500
	Wheel goods, sports, and photographic equipment, boats, and pleasure aircraft		0.0625	0.1650
	Books and maps		0.0328	0.1650
	Ophthalmic products and orthopedic appliances		0.0500	0.2750
	China, glassware, utensils		0.0370	0.1650
China average depreciation rate (2009)				0.1601
US average depreciation rate (2009)				0.1584

Notes: Shares of durable categories consumption in China are derived from our UHS data. Shares of durable categories consumption in the U.S. are drawn from the BEA (https://apps.bea.gov/iTable/?reqid=19&step=3&isuri=1&1921=underlying&1903=2017).
BEA depreciation rates are from: https://apps.bea.gov/scb/account_articles/national/0797fr/table3.htm#fn11. These are time invariant and based on Hulten and Wykoff (1981a).
* BEA does not contain a number for autos' depreciation. Hulten and Wykoff (1981a) imply depreciation rates for cars in the range 0.13-0.33. We use a depreciation rate of 0.165 that is the rate BEA uses for the depreciation of state and local governments' motor vehicles.
** The share of the consumption of autos in the U.S. also includes other motor vehicles.
*** Depreciation rate for communication equipment from private nonresidential equipment
**** U.S. consumption shares sum up to less than 1 (=0.952), as tires and other auto parts are included in the BEA statistics as durables but assumed to depreciate at a rate of 0.61. Chinese data does not include this category as durable goods but subsumes them with fuel as non-durables. Also, Chinese data do not include China, glassware, and utensils/books and maps/Ophthalmic products and orthopedic appliances as durable categories (given their relatively negligible consumption shares their inclusion into this category is not going to affect the imputed depreciation rate significantly.

Table 4: The depreciation rate in China and the U.S. using depreciation rates of durable goods categories from the Bureau of Economic Analysis.

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Online Appendix

A Appendix for Section 2

A.1 Proof of Proposition 1

Proof. With $\beta(1+i_t)P_{t+1}/P_t = 1$, $C_t = C_{t+1}$. Investment is then defined as

$$I_t = c_{d,t+1} - (1-\delta)c_{d,t} = (1-\alpha)C_t\left[\left(\frac{\hat{p}_{d,t+1}}{P_{t+1}}\right)^{-\varepsilon} - (1-\delta)\left(\frac{\hat{p}_{d,t}}{P_t}\right)^{-\varepsilon}\right].$$

Linearizing this expression around $g = 0$ (i.e., around $\hat{p}_{d,t+1} = \hat{p}_{d,t}$ and $P_{t+1} = P_t$), we get

$$\left(\frac{\hat{p}_{d,t+1}}{P_{t+1}}\right)^{-\varepsilon} \approx \left(\frac{\hat{p}_{d,t}}{P_t}\right)^{-\varepsilon}(1-\varepsilon(g-g_p))$$

where g_p is the deterministic growth rate of the aggregate price index. The aggregate price index is

$$P_{t+1} = (\alpha + (1-\alpha)\hat{p}_{d,t+1}^{1-\varepsilon})^{1/(1-\varepsilon)}$$

which linearized around $g = 0$ is

$$P_{t+1} \approx P_t + P_t(1-\alpha)\left(\frac{\hat{p}_{d,t}}{P_t}\right)^{1-\varepsilon} g = P_t(1+\chi_{d,t}g)$$

such that $g_p = \chi_{d,t}g$. We thus have

$$\left(\frac{\hat{p}_{d,t+1}}{P_{t+1}}\right)^{-\varepsilon} \approx \left(\frac{\hat{p}_{d,t}}{P_t}\right)^{-\varepsilon}(1-\varepsilon g(1-\chi_{d,t})) = \left(\frac{\hat{p}_{d,t}}{P_t}\right)^{-\varepsilon}(1-\varepsilon g\chi_{n,t}),$$

where we use the definition that $\chi_{n,t} + \chi_{d,t} = 1$. Inserting this into the original expression, we get

$$I_t \approx (1-\alpha)C_t\left(\frac{\hat{p}_{d,t}}{P_t}\right)^{-\varepsilon}[(1-\varepsilon g\chi_{n,t}) - (1-\delta)] = (1-\alpha)C_t\left(\frac{\hat{p}_{d,t}}{P_t}\right)^{-\varepsilon}(\delta - \varepsilon g\chi_{n,t}).$$

The observable spending share on durables is then

$$p_{d,t}I_t \approx (\delta - \varepsilon g\chi_{n,t})(p_{d,t}/P_t)^{1-\varepsilon}\frac{1-\alpha}{(i_t+\delta-g)^{\varepsilon}}P_tC_t$$

and the observable spending on non-durables is $c_{n,t} = \alpha(1/P_t)^{1-\varepsilon}P_tC_t$. □

A.2 Proof of Proposition 2

Proof. The spending on durable goods is

$$p_{d,t}c_{d,t} = (1-\alpha)p_{d,t}(\hat{p}_{d,t}/P_t)^{-\varepsilon}C_t = (p_{d,t}/P_t)^{1-\varepsilon}\frac{1-\alpha}{(i_t+\delta-g)^{\varepsilon}}X_t.$$

When households adjust their level of durable consumption, a change in $c_{d,t}$ equals investment I_t. We therefore replace $c_{d,t}$ with I_t such that

$$d(p_{d,t}I_t) = (p_{d,t}/P_t)^{1-\varepsilon}\frac{1-\alpha}{(i_t+\delta-g)^{\varepsilon}}dX_t.$$

The marginal spending on non-durable goods is

$$dc_{n,t} = \alpha(1/P_t)^{1-\varepsilon}dX_t.$$

□