Time Preferences, Mortgage Choice and Mortgage Default

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Abstract

The recent financial crisis has led to calls for a better understanding of the pattern of behaviour behind the increase in mortgage defaults and the foreclosures. Previous studies using option-based mortgage default models predicted that borrowers should exercise the default option when the market value of their mortgage exceeds the value of the underlying property. However, empirical evidence shows that a substantial number of borrowers do not default as 'ruthlessly' as the option theory predicts. This indicates that mortgage borrowers are more heterogeneous compared to investors in asset classes, such as bond and stock markets. In this paper, we hypothesize that difference among time preferences across mortgage choices is one of the underlying factors that causes the heterogeneity in default patterns. Borrowers can either have a present-biased preference (overvaluing immediate outcomes), or a time-consistent preference (standard exponential discounting). Borrowers with a present-biased preference are more likely to accept back-loaded mortgages that minimize up-front costs, even though this increases their risk of going "underwater" and entering default when negative home price shocks occur.

Keywords: Mortgage default, mortgage choice, heterogeneity, present-biased preference, dynamic inconsistency

JEL Codes: D1, D9, G1, R2

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1. Introduction

The financial crisis of 2008 triggered by the stunning rise of subprime mortgage delinquencies has led to a re-evaluation of mortgage defaults and foreclosures. In the past five years, millions of homeowners in the United States "walked away" and allowed their homes to be foreclosed. Moreover, according to Core Logic's negative equity report, owners of 11.1 million residential properties were in negative equity (i.e. they were "underwater") and at the risk of foreclosure by the end of 2011.[1] Table 1 lists the ten states with the highest levels of negative equity and near negative equity in the United States.[2] Compared with borrowers who simply "walked away" and those in default, most underwater homeowners still continued to make their mortgage payments. However, it is difficult to know beforehand which borrowers will be in default, because there is significant heterogeneity among them. This leads us to wonder why some homeowners choose to default on their mortgages, while others do not.

Insert Table 1 about here

This paper studies whether heterogeneity in borrowers' time preferences correlates with their decision to default on their mortgage payments. Borrowers' time preferences are measured using their choice of mortgage type. In particular, it investigates borrowers who exhibit present-biased preference, that is, those who are more likely to accept back-loaded mortgages that minimize up-front costs and place them at greater risk of becoming underwater and default following negative home price shocks.

After the pioneering work by Asay (1978), there was a quick expansion of studies on mortgage valuation and borrower behavior based on the contingent claims models, mainly developed by Black and Scholes (1973), Merton (1973a), Cox, Ingersoll, and Ross (1985). The contingent claims model provides a useful framework for analysing borrowers' behavior, in which prepayment is treated as an American call option and default as a compound put option. The "pure" option-theoretic mortgage pricing models assume that a well-informed borrower will default immediately when the mortgage

[1] http://www.corelogic.com/about-us/news/corelogic-reports-negative-equity-increase-in-q4-2011.aspx Accessed on March 15, 2012.

[2] Properties that are in negative equity, where the borrower owes more on their mortgage than the property's current market value, are often termed as being "underwater" or "upside down". Mortgages that are within five percent of being in a negative equity position are defined by CoreLogic as being "near negative equity".

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value exceeds the value of his/her property at any time during the loan term (Titman and Torous 1989; Kau, Keenan, and Kim 1994). These models assume a perfectly competitive market without any transaction or reputation costs, and no exogenous reasons for residential mobility. Despite a frictionless market being an ideal case, negative equity may be a necessary, but not a sufficient, condition to trigger default (Vandell 1995; Deng 1997, Deng, Quigley, and Van Order 2000; Bajar, Chu, and Park 2008). Evidence shows that a substantial number of borrowers are unlikely to default as 'ruthlessly' as the option theory predicts. White (2010b) argued that not all homeowners who were underwater on their mortgage walked away from their homes immediately during the recent financial crisis, including those who lived in "nonrecourse states", such as California and Arizona.[3] Although such behavior may appear irrational on its face, the homeowners who stayed and those who walked away all struggled with the same decision: to continue paying their mortgage or not.

Many empirical studies have tried to explain this 'irrational' phenomenon using the option-based framework. The anecdotes underlying these studies emphasize that the transaction costs resulting from default are pervasive and significant (Stanton 1995; Archer, Ling, and McGill 1996; Harding 1997).[4] These studies assume that these transaction costs, which include moving costs, reputational issues, and default penalties, are high enough to deter homeowners from leaving their homes. In addition to the economic consideration of transaction costs, recent attention has been paid on the emotional constraints to strategic default. Guiso, Sapienza, and Zingales (2013), using survey data, documented that social and moral considerations may play a partial role in explaining the willingness of homeowners to continue to pay their underwater mortgages. White (2010b) also argued that the shame or guilt associated with foreclosure and fear over the perceived consequences of foreclosure led those underwater homeowners choose not to default.

The role of transaction costs is important in determining the exercise of both the default and prepayment options. What causes default borrowers to accept the economic and emotional transaction costs that accompany their default decision? The empirical

[3] In non-recourse states, lenders cannot pursue defaulting homeowners for a deficiency judgment. While lenders can recover some of their losses by foreclosing on the property, they cannot sue borrowers for additional funds. If the foreclosure sale does not generate enough money to satisfy the loan, lenders must accept the losses.

[4] For an explicit discussion about these transaction costs, see Kau, Keenan, and Kim (1993).

unobserved heterogeneity of mortgage borrowers has been discussed extensively in the literature, but only as an unproven assumption. For example, Deng, Quigley and Van Order. (2000) assumed that borrowers are heterogeneous agents who form discrete groups, and Hall (2000) assumed that these agents have different distributions of underlying hazards. Stanton (1995, 1996) and others have also argued that heterogeneity exists within mortgage pools. Deng and Quigley (2002) presents a model of borrower behavior in the mortgage market in which some correlates of the unobserved heterogeneity of individual borrowers are observed, without being limited by specifying a restrictive functional form or an arbitrary constellation of mass-points of population heterogeneity. However, researchers have been unable to provide a theoretical framework for this unobserved heterogeneity or explain its origins.

The present study tries to fills this gap by assuming that this unobserved heterogeneity is based on borrowers' time preferences, and it examines whether heterogeneity in borrowers' time preferences is correlated with their mortgage default decisions. Two kinds of time preferences exist for borrowers, with corresponding discounting factors: present-biased preference (overvaluing immediate outcomes), and time-consistent preference (standard exponential discounting). The key distinction between these two is the presence and absence of a "present bias". Individuals with present-biased preference prefer immediate gratification, and, as a result, are more likely to minimize their up-front costs and postpone their mortgage payment. They are thus more likely to select back-loaded mortgages, such as interest-only loans. This selection is more likely to place them at a higher risk of going underwater and defaulting following negative home price shocks.

We hypothesize that naïve borrowers with present-biased preference are more likely to select interest-only loans which allow them to enjoy the immediate benefits of homeownership and postpone their mortgage payment costs. Sophisticated borrowers with present-biased preference, on the other hand, are fully aware of their future self-control problems, and know their future preference exactly, even though they may differ from their current preference. Therefore, they are smart and more likely to choose 30-year adjustable-rate loans. In contrast, borrowers with time-consistent preference tend to choose 30-year fixed-rate loans, which are fully amortizing mortgage loans where the interest rate on the note remains the same through the term of the loan.

We analyse mortgage data at the level of individual loans, principally collected by BlackBox Logic (BBL), and home loan application and origination data, collected by the Home Mortgage Disclosure Act (HMDA), using a logistic regression to examine how borrowers' time preferences influence their mortgage choice and their default decisions. The fixed effects are the year of origination, year of termination, and the state in which the property is located. Firstly, the default behavior of naïve borrowers who selected interest-only loans, relative to those who selected 30-year fixed-rate loans is studied. The results indicate that borrowers with 5-year interest-only loans are around 41 percentage points more likely to default than those who selected 30-year fixed-rate loans. In addition, borrowers with 10-year interest-only loans are around 47 percentage points more likely to default than dynamically-consistent borrowers who chose 30-year fixed- rate loans.

We further study the default behaviour of borrowers who chose 30-year adjustable-rate loans relative to those who chose 30-year fixed-rate loans. We found that sophisticated borrowers who chose 30-year adjustable-rate loans are 27 percentage points more likely to default than borrowers who selected 30-year fixed-rate loans. In other words, the default rate of sophisticated borrowers with present-biased preference is higher than borrowers with time-consistence preference.

Lastly, we examine the default behaviour of both interest-only loans and 30-year adjustable-rate loans relative to those who selected 30-year fixed-rate loans. The results indicate that present bias is highly correlated with mortgage default, and borrowers who exhibit present-biased preference in their choice of mortgages have a substantially higher probability of default. Borrowers with 5-year interest-only loans are around 35 percentage points more likely to default than those who selected 30-year fixed-rate loans, and borrowers with 10-year interest-only loans are around 39 percentage points more likely to default than dynamically-consistent borrowers who chose 30-year fixed-rate loans. In addition, the default probability of borrowers with 30-year adjustable-rate loans is 24% higher than borrowers who chose 30-year fixed-rate loans. The association between present bias and mortgage default holds when controlling for other loan characteristics and housing price. Moreover, all of the results hold after using propensity score matching, based on borrowers' characteristics (including income, race, sex) and loan characteristics (e.g. original loan balance, location of property, origination year etc.) for different loan types. These results are therefore the first direct support for

the claim that the mortgage default decisions of borrowers is related to their different time preferences.

This paper contributes to several strands of the existing literature. First, it contributes to the broader literature on mortgage default. It presents an alternative theory to explain the origins of the unobserved heterogeneity of mortgage borrowers and how this unobserved heterogeneity affects borrowers' default decisions and behaviors. The "frictionless" market is an ideal assumption, and transaction costs have a significant impact on the likelihood of individuals' decisions to strategically default or prepay. Foster and van Order (1984) found that borrowers would not default "ruthlessly", and exercised the put option of default if the value of their house fell below the mortgage value by an amount equal to the net transaction costs. Therefore, we argue that a pure option-based theory cannot fully explain mortgage default behavior, and the impact of transaction costs on the mortgage default decision is important (Cunningham and Hendershott 1984; Foster and Van Order 1984, 1985; Vandell and Thibodeau 1985; Quigley and Van Order 1991; Lekkas, Quigley, and Van Order 1993). In addition to the above studies that conjecture the existence of transaction costs, some other studies try to test the importance of transaction costs and incorporate them into default risk modelling. For example, Lekkas et al. (1993) and Quigley and Van Order (1995) explicitly tested the 'frictionless' models, and validated the importance of transaction costs besides equity position.[5] Deng et al. (2000), Deng, Pavlov, and Yang (2005), and Clapp, Deng, and An (2006) stressed the importance of borrower and spatial heterogeneity associated with transaction costs.[6] Kau, Keenan, and Kim (1993) and Kau and Slawson (2002) included both transaction costs and suboptimal termination into mortgage pricing models.

At the same time, transaction costs are complicated and differ across mortgage holders, creating significant unobserved heterogeneity among borrowers. The role of unobserved borrower heterogeneity in explaining mortgage termination has also attracted much attention. Richard and Roll (1989), Schwartz and Torous (1989), and

[5]Clauretie (1987) and Hendershott and Schultz (1993) explicitly included non-equity variables, like costs of foreclosure, unemployment rate and showed their significance for foreclosure rates.
[6]Other examples incorporating market imperfections to "frictionless" models include Vandell et al. (1993), Archer et al. (2002), Van Order and Zorn (2000), Clapp et al. (2001), Pavlov (2001), Calhoun and Deng (2002), Goldberg and Harding (2003), etc.

Archer, Ling, and McGill (1996) all suggested the existing of ad hoc variables in analysis of pools, and addressed heterogeneity within mortgage pools. Stanton (1995, 1996) extended previous research to handle heterogeneity between mortgage pools. Deng et al. (2000) considered the issue of unobserved heterogeneity in the context of hazard modelling, and they explicitly accounted for the unobserved heterogeneity among borrowers by adding discretely distributed mass point mixed hazard. This research has been followed by Clapp, Deng and An (2006). Although transaction costs and unobserved heterogeneity have been discussed extensively in empirical studies, there is no unifying theory to explain the underlying unobserved heterogeneity of borrowers.

This paper also adds to the literature on individual different time preferences, which has been addressed both in psychology and behavioral economics. Past research has documented that individual differences in time preference are an important predictor in many life choices such as gym contracts (DellaVigna and Malmendier 2006), smoking (Gul and Pesendorfer 2007), body-mass index (Smith, Bogin, and Bishai 2005; Courtemanche and Carden 2011), savings for retirement (Carroll et al. 2009), and credit card debt (Laibson, Repetto, and Tobacman 2007; Chabris, Laibson, and Schuldt 2008; Reimers et al. 2009; Meier and Sprenger 2010; Kuchler, 2013). In addition, Krusell, Kuruscu, and Smith (2010) analysed the effects of present bias on optimal taxation. DellaVigna and Paserman (2005) used present bias preference to explain individual job search behaviour. However, researchers have not studied the effects of present bias on mortgage choice and default, and relatively few papers on mortgage choice and default have distinguished between naïve and sophisticated individuals. In this paper, heterogeneous time preferences among borrowers, as indicated by their mortgage choices, are used to explain the default behavior of present-biased borrowers. Different mortgage types are also used to differentiate naïve and sophisticated borrowers.

The rest of this paper is organized as follows: in Section 2, following the original work of Phelps and Pollak (1968) (later employed by Laibson (1994, 1997, 1998) and other papers), a typical form of present-biased preference (i.e., quasi-hyperbolic) is presented; time preferences and mortgage choices are illustrated in section 3; section 4 outlines and describes the data used for this paper; section 5 discusses the default behavior for different mortgage types using a logistic model, and Section 6 concludes the paper.

2. Present-Biased Preference

Traditional inter-temporal preference models in economics have captured the impatience of agents by using exponential discounting. This approach explicitly assumes that preferences are inter-temporally consistent. However, this standard economic assumption may not be applicable in all instances when we are considering trade-offs between two future moments. Specifically, individuals with present-biased preference tend to give relatively more weight to nearer moments in the future as they get closer, and their inter-temporal preferences are time inconsistent (O' Donoghue and Rabin 1999a).

One way of modelling present-biased preference is to use "quasi-hyperbolic discounting" or "(β, δ)-preference". This method was originally developed by Phelps and Pollak (1968), and was later employed by Laibson (1994, 1997, 1998) to capture self-control problems within an individual. This method is widely used in the literature (e.g. O' Donoghue and Rabin 1999a, 1999b, 1999c, 2001; Carrillo 1999; Fischer 2001) and will be used in this paper.

Let u_t be the instantaneous utility the borrower gets in period t, and $U(u_t, u_{t+1}, u_{t+2}, \dots, u_T)$ be the borrower's inter-temporal preference function from the perspective of period t. Borrowers are assumed to have quasi-hyperbolic preference. Time is divided into two periods: the present period (t) and all future periods (beginning from t+1 to T). The inter-temporal preference function for borrowers with present-biased preference can be expressed as:

$$(1) \qquad U(u_t, u_{t+1}, u_{t+2}, \dots, u_T) = \delta^t u_t + \beta \sum_{\tau=t+1}^{T} \delta^\tau u_\tau$$

$$\text{for } t \in [1, T];\ 0 < \delta \leq 1;\ 0 < \beta \leq 1$$

As in the standard exponential discounting model, the parameter δ represents the "time-consistent" long-run discounting factor. In this inter-temporal preference model, an additional parameter β is added into the standard time-consistent model for the future period to capture an individual's "bias for the present" – i.e., the agent's preference for the current over all future periods. There are two types of β: $\beta = 1$ and $0 < \beta < 1$.

For $\beta = 1$,

$$U(u_t, u_{t+1}, u_{t+2}, \dots, u_T) = \sum_{\tau=t}^{T} \delta^{\tau} u_{\tau} \quad (2)$$

The inter-temporal preference function reduces to a standard exponential discounting utility function with time-consistent inter-temporal preference (the discrete version). Under this time preference, borrowers treat the present period and all future periods the same.

For $0 < \beta < 1$,

$$U(u_t, u_{t+1}, u_{t+2}, \dots, u_T) = \delta^t u_t + \beta \sum_{\tau=t+1}^{T} \delta^{\tau} u_{\tau} \quad (3)$$

This function parsimoniously captures present-biased preference, and greater weight is assigned to the present relative to the future. The β-parameter in this model thus fully captures the dynamic-inconsistency suggested by present-biased preference (O' Dognohue and Rabin 1999a, 1999b 1999c).

If time-inconsistent preference is assumed, an individual at each time period is modelled as a separate agent who maximizes utility according to her current preference, while her "future selves" will control her future behavior based on the prevailing preferences in the future (O'Donoghue and Rabin 1999a). An important question following this assumption is: what does an individual believes about her future selves' preferences? A crucial insight from the present-biased preference perspective is the distinction between naïve and sophisticated individuals. A sophisticated individual is fully aware of his/her future self-control problems, and knows his/her future selves' preferences exactly, even though they may differ from those of the current self. In contrast, a naïve individual does not anticipate his/her future procrastination, and is thus fully unaware of her future self-control problems. This inclines his/her to believe that his/her future preferences will be identical to his/her current ones. Under such a distinction, choices of naïve individual and sophisticated individual are different.

3. Time Preferences and Mortgage Choice

Selecting a mortgage is a consequential consumer choice that highlights the role of time preferences in determining outcomes.[7] While mortgage are often complex and differ along many dimensions, they can be broadly classified into two main categories based on their repayment structure: back-loaded mortgages and front-loaded mortgages. A second dimension of interest is the length of repayments. Mortgage contracts typically involve repayment periods of 30-year, but can also be structured for shorter periods, such as 10-year. The selection of a particular payment structure is an indication of a borrower's intertemporal preferences.

A fixed-rate mortgage (FRM) is a fully amortizing mortgage loan where the interest rate on the note remains the same through the term of the loan, as opposed to "floating" loans where the interest rate may adjust. As a result, the payment amounts and loan duration of an FRM are fixed and the person who is responsible for paying back the loan benefits from a consistent, single payment and the ability to plan a budget based on this fixed cost. The constant discounting for fixed-rate mortgage implies that a person's intertemporal preferences are time-consistent, which means that any decision that the individual makes for himself in advance will remain valid as time advances, and later preferences "confirm" earlier preferences. Therefore, borrowers with time-consistent preference (standard exponential discounting) will choose fixed-rate mortgages.

An interest-only loan is a loan in which, for a set term, the borrower pays only the interest on the principal balance, with the principal balance unchanged. At the end of the interest-only term, the borrower may enter an interest-only mortgage, pay the principal, or (with some lenders) convert the loan to a principal and interest payment (or amortized) loan at his/her option. Mortgages such as interest-only loans are particularly appealing to present-biased individuals because they present lower upfront costs in return for greater later costs. In addition, with the absence of self-control, interest-only loans are more likely to be selected by naïve borrowers who are fully

[7] Carroll et al. (2009) modelled the optimal policies of 401(k) saving for present biased consumers; DellaVigna and Malmendier (2004) studied the present biased consumers' contract choice among health club, and concluded that consumer's preferences among contract were important; Prelec and Loewenstein (1998) illustrated how payment and consumption events can be optimally timed and linked.

unaware of their future self-control problems, minimize their up-front costs and postpone the payment on their mortgages.

In contrast, 'sophisticated' borrowers who have present-biased preference, or suffer from short-term temptations and are aware of the consequences, are likely to prefer to control themselves from temptation and behave more rationally. When selecting a mortgage, sophisticated borrowers may be worried about the minimal up-front costs and the corresponding future over-payments, and may refrain from them so as to induce themselves to resist temptation in the future. This means that, unlike naïve borrowers, sophisticated borrowers will not choose interest-only loans. However, they will also not choose fixed-rate loans, which would be preferred by time-consistent borrowers. An adjustable-rate mortgage (ARM) is a mortgage loan where the interest rate on the note is periodically adjusted based on an index which reflects the cost to the lender of borrowing on the credit markets. Adjustable-rate mortgage loans are similar to interest-only loans, in that they allow borrowers to enjoy minimal up-front costs, and differ from fixed-rate mortgage loans, in that loan repayments are not a consistent amount. Therefore, sophisticated borrowers with self-control will be more likely to choose an adjustable-rate mortgage.

4. Data

Two main sources of data are used in this paper: individual loan-level mortgage data, from BlackBox Logic (BBL), and the database of home loan applications and originations collected by the Home Mortgage Disclosure Act (HMDA).

BlackBox Logic (BBL) is a private company that provides a comprehensive, dynamic dataset with information about twenty-one million privately securitized subprime, Alt-A, and prime loans in the United States. These loans account for about ninety percent of all privately securitized mortgages. The BlackBox data, which is obtained from mortgage services and securitization trustees, includes static information taken at the time of the origination of mortgages, such as the mortgage contract date, original loan amount, the initial loan-to-value ratio, borrowers' FICO credit scores, mortgage service name, mortgage contract interest rate, mortgage term, interest rate type, state, region, and major metropolitan area in which the property is located. In addition, the BlackBox

data also include dynamic data on monthly payments, mortgage balances, current loan to value ratio, and delinquency status.

The HMDA database is available at the loan application level.[8] It is an annual database that contains each applicant's final status (denied/approved/originated), purpose of borrowing (home purchase/refinancing/home improvement), loan amount, borrowers' attributes (race, gender, income, and home ownership status), and also (in the case of originated loans) whether the loan was sold to the secondary market within the year. In addition, the location of property is clearly recorded in the HMDA database.

The analysis in this paper is confined to first-lien mortgage loans issued between 1995 and 2011, and includes those loans that were either closed or still active at the third quarter of 2012. The analysis is confined to 5-year interest-only loans, 10-year interest-only loans, 30-year fixed-rate loans and 30-year adjustable-rate loans. After removing mortgages with incomplete information on LTV ratio, original loan balance, FICO score and other key information, the final sample includes 3,058,413 individual mortgages.

Figure 1 shows the distribution of loan origination over the years. Generally, the number of all kinds of loans grew tremendously between 2001 and 2006. In 2005, the number of originations of interest-only loans and adjustable-rate loans reached a peak. The number of fixed-rate loans originations peaked in 2006. Before 2003, the origination of fixed-rate loans dominated the loan market, and this changed from 2004. The origination of interest-only and 30-year adjustable-rate loans expanded very quickly from 2004. Moreover, the number of interest-only loans grew at a faster rate than both fixed-rate loans and adjustable-rate loans. After the financial crisis, the origination of all kinds of loans decreased sharply.

Figure 2 focuses on the loan origination growth in four states (i.e., California, Florida, Arizona and Nevada). Consistent with the dramatic growth as shown in Figure 2-1, the origination of all kinds of loans grew tremendously between 2001 and 2006 in these four states. In addition, the origination of interest-only loans increased particularly fast

[8] The Home Mortgage Disclosure Act (HMDA), enacted by Congress in 1975 and implemented by the Federal Reserve Board, requires lending institutions to report public loan data. The lending institutions mainly include banks, savings associations, credit unions, and other mortgage lending institutions.

in California (CA), Arizona (AZ) and Nevada (NV). In these three states, the origination of interest-only loans in 2005 and 2006 was more than twice the number of 30-year fixed-rate loans. Consistent with Figure 1, the number of originations for all kinds of loans dropped sharply since the financial crisis began.

Insert Figure 1 about here

Insert Figure 2 about here

Table 2 shows the summary statistics of the BlackBox (BBX) dataset. Information on three types of first-lien mortgage loan originations between 1995 and 2011 are kept: interest-only loans (5-year and 10-year), 30-year fixed-rate loans and 30-year adjustable-rate loans. 26.7% of the loans are interest-only loans, with 10.62% being 5-year interest-only loans and 16.08% 10-year interest-only loans. 36.31% of the loans are 30-year fixed-rate loans, and 36.99% are 30-year adjustable-rate loans. Borrowers have an average FICO score of 663.52, and borrowed up to 79.15% of the property value (LTV) in the sample.

Columns (2) to (4) show the summary statistics for each loan type separately. Nearly 40% of interest-only loans are 5-year interest-only loans. Loans and borrowers have distinct characteristics for each loan type. The average amount borrowed is the highest among interest-only loans, nearly two times the amount borrowed for 30-year adjustable-rate loans. The FICO scores for interest-only loans are the highest with an average of 699.496. Borrowers who opted for 30-year adjustable-rate loans have the lowest FICO score of 617.575. The average amount borrowed for interest-only loans and 30-year fixed-rate loans is similar, and is up to 77% of the property's value. However, the average amount borrowed for 30-year adjustable-rate loans is much higher than other types of loans, up to 82.5% of the property's value.

Insert Table 2 about here

Figure 3 suggests the default pattern for each type of loan over the period being studied. The default rate for each type of loan increased dramatically after the recent financial crisis, especially for interest-only loans and 30-year adjustable-rate loans. Both the default frequency and default percentage reached their peaks in 2011 for all kinds of loans. In addition, it can be seen, from both the frequency and percentage of default distributions, that the default rate for interest-only loans and 30-year adjustable-rate

loans is much higher than 30-year fix-rate loans from 2008 to 2011. Figure 4 suggests that the default patterns in the four states are consistent with the full sample. Particularly, the default frequency for interest-only loans after the recent financial crisis is much higher than the default frequency for others type of loans in CA, AZ and NV.

Insert Figure 3 about here

Insert Figure 4 about here

5 Empirical Results

5.1 Time Preferences and Mortgage Default

We use logistic regression to study the default behaviour of interest-only loans and 30 year adjustable-rate loans, relative to 30-year fix-rate loans. Table 3 reports the regression coefficients and odds ratios in the full sample analysis. Consistent with existing findings on the determinants of the default behavior, owner-occupancy, lower LTV ratio, high FICO score and lower loan balance predict a lower default rate in general. In addition, lower or no documentation loans are risky, and their default probabilities are higher. Column (1) shows the regression results of interest-only loans relative to 30-year fixed-rate loans. It can be seen that 5-year interest-only loans are 41% more likely to default than 30-year fixed-rate loans after controlling other loan characteristics. The default probability for 10-year interest-only loans is 47.4% higher than that for 30-year fixed-rate loans, after controlling other loan characteristics.

The results in column (2) show the regression results for 30-year adjustable-rate loans relative to 30-year fixed-rate loans. 30-year adjustable-rate loans are 26.8% more likely to default compared with 30-year fixed-rate loans, after controlling for other loan characteristics. The last column shows the results in the full sample analysis, where the default probabilities for both interest-only loans and 30-year adjustable-rate loans relative to 30-year fixed-rate loans are presented. Compared with 30-year fixed-rate loans, the default probability of 5-year interest-only loan is 34.9% higher, and that for 10-year interest-only loans is 39.3% higher. 30-year adjustable-rate loans are 24.4% more likely to default relative to 30-year fixed-rate loans. Moreover, the default probability of 30-year adjustable-rate loans is lower than interest-only loans.

Insert Table 3 about here

Table 4 presents the sub-sample default analysis in California, Florida, Arizona and Nevada respectively. As shown in Figure 2 and Figure 4, the patterns of origination and default for each loan type in these four states are similar to the full sample. Consistent with the results from the full sample, the average default rates for interest-only loans and 30-year adjustable-rate loans are higher relative to 30-year fixed-rate loans, and the default probability of 30-year adjustable-rate loans is lower than interest-only loans. However, compared with the results in Table 3, the default probability of interest-only loans relative to 30-year fixed-rate loans in these four states is higher than the general results, and the default probability of 30-year adjustable-rate loans relative to 30-year fixed-rate loans in these four states is lower than the general results. In particular, in California, borrowers of 5-year interest-only loans are around 58.6 percentage points more likely to default than those who selected 30-year fixed-rate loans, and 10-year interest-only loans borrowers are around 64.5 percentage points more likely to default than those who selected 30-year fixed-rate loans. On the other hand, in California, 30-year adjustable-rate loans borrowers are around 25.6 percentage points more likely to default than those who have selected 30-year fixed-rate loans.

Insert Table 4 about here

Table 5 presents the sub-sample default analysis by setting the financial crisis as a break point. Specifically, the sample is divided into two parts: loans that terminated before the financial crisis and loans that terminated after financial crisis.[9] Generally speaking, for both before and after financial crisis sample, all results are consistent with the results in the full sample. Before the financial crisis, 5-year interest-only loans were 14.5% more likely to default than 30-year fixed-rate loans, after controlling for other loan characteristics. The default probability for 10-year interest-only loans is only 8.9% higher than that for 30-year fixed-rate loans, after controlling other loan characteristics.

The results changed dramatically after the financial crisis. 5-year interest-only loans were 44% more likely to default than 30-year fixed-rate loans, after controlling for other loan characteristics. The default probability of 10-year interest-only loans was 50.6% higher than 30-year fixed-rate loans. However, the results for 30-year adjustable-rate

[9] For simplicity, the financial crisis is defined as beginning at the start of 2009. Therefore, the two parts of the sample are: loans that terminate before the end of 2008 and loans that terminate after the beginning of 2009.

loans compared to 30-year fixed-rate loans were the same. This divergence in the findings can be explained by the higher probability for back-loaded mortgages that minimize up-front costs to go "underwater" and default following negative home price shocks.

Insert Table 5 about here

5.2 Robustness Analysis: Propensity Score Matching

The original loan size and other observable attributes of each loan type are systematically different (see Table 1), and directly comparing their default may be misleading with an unbalanced sample. Therefore, propensity score matching (PSM) is used to obtain a more homogeneous sample for each comparison sample to mitigate the potential bias.[10] Specially, a one-to-one match for each treatment group based on the original loan balance, origination year, location of property (MSA level) and other loan and borrower characteristics is performed.

Table 6 reports the summary statistics of the matched sample. Although propensity score matching is not able to entirely eliminate the difference in loan and borrower characteristics of the interest-only loans and 30-year adjustable-rate loans relative to the 30-year fixed-rate loans, the gap between those observables is greatly reduced across these three loan types after matching. Firstly, interest-only loans (the treatment group) are matched with 30-year fixed-rate loans (the control group) to mitigate the potential bias. In the matched sample, 22.44% the loans are 5-year interest-only loans and 27.56% are 10-year interest-only loans. The statistics of all the variables are very similar after matching for interest-only loans and 30-year fixed-rate loans. Second, the summary statistics are shown by matching 30-year adjustable-rate loans (the treatment group) with 30-year fixed-rate loans (the control group). Lastly, both interest-only loans and 30-year adjustable-rate loans (the treatment group) with 30-year fixed-rate loans (the control group) are matched. After matching, 22.08% of the loans are interest-only loans, with 8.54% having a duration of 5-year and 13.54% being 10-year long, and

[10] The BlackBox dataset has fewer borrowers' characteristics than the HMDA dataset. Therefore, firstly, the HMDA dataset is matched with the BlackBox dataset to obtain more information about mortgage borrowers, including borrowers' race, sex, income, and home ownership status. Then the propensity score matching is carried out based on the combined information from both datasets.

27.64% of the loans are 30-year adjustable-rate loans. In the treatment group, 44.72% of the loans are interest-only loans, with 17.08% being 5-year interest-only loans, 27.65% being 10-year interest-only loans, and 55.28% of the loans being 30-year adjustable-rate loans.

Insert Table 6 about here

Table 7 presents the results of the logistic regression analysis on the default behavior of interest-only loans and 30-year adjustable-rate loans relative to the 30-year fixed-rate loans in the matched sample. The findings are broadly consistent with those in Table 3: in the matched sample, the average default rate of interest-only loans and 30-year adjustable-rate loans is higher relative to that for 30-year fixed-rate loans, and the default probability for 30-year adjustable-rate loans is lower than that for interest-only loans.

Column (1) shows the regression results of interest-only loans relative to 30-year fixed-rate loans after matching. It can be seen that 5-year interest-only loans are 49.4% more likely to default than 30-year fixed-rate loans after controlling for other loan characteristics. In addition, the default probability of 10-year interest-only loans is 44.8% higher than 30-year fixed-rate loans after controlling for other loan characteristics. The results in column (2) have shown that 30-year adjustable-rate loans are 22.6% more likely to default compared to 30-year fixed-rate loans, after controlling for other loan characteristics and propensity matching. The last column shows the results in the full sample analysis, where the default probabilities of both interest-only loans and 30-year adjustable-rate loans relative to those for 30-year fixed-rate loans are presented. Compared with 30-year fixed-rate loans, the default probability of 5-year interest-only loans is 30.9% higher, and 31.6% higher for 10-year interest-only loans. The 30-year adjustable-rate loans are 21.7% more likely to default relative to 30-year fixed-rate loans. Moreover, the default probability of 30-year adjustable-rate loans is lower than the default probability of interest-only loans.

Insert Table 7 about here

Table 8 presents the sub-sample default analysis in California, Arizona, Florida and Nevada respectively in the matched sample. The results are consistent with those in Table 4: the average default rates of interest-only loans and 30-year adjustable-rate

loans are higher relative to 30-year fixed-rate loans, and the default probability of -year adjustable-rate loans is lower than that for interest-only loans. The default probability of interest-only loans is particular high in California, where borrowers of 5-year interest-only loans are around 70.1 percentage points more likely to default than those who selected 30-year fixed-rate loans, and borrowers of 10-year interest-only loans are around 56.2 percentage points more likely to default than those who selected 30-year fixed-rate loans.

Insert Table 8 about here

Table 9 presents the sub-sample default analysis by setting the financial crisis as a break point in the matched sample. The results are consistent with those shown in Table 5: the default probabilities of both interest-only loans and 30-year adjustable-rate loans are higher than 30-year fixed-rate loans. However, there is a great deal of difference between the results before and after financial crisis. Before the financial crisis, borrowers of 5-year interest-only loans were around 20.4 percentage points more likely to default than those who selected 30-year fixed-rate loans, and borrowers of 10-year interest-only loans were around 7.8 percentage points more likely to default than those who selected 30-year fixed-rate loans. After the financial crisis, borrowers of 5-year interest-only loans were around 51.3 percentage points more likely to default than those who selected 30-year fixed-rate loans, and borrowers of 10-year interest-only loans are only around 47.5 percentage points more likely to default than those who selected 30-year fixed-rate loans. The results for 30-year adjustable-rate loans relative to 30-year fixed-rate loans are similar.

Insert Table 9 about here

5.3 Loans that Originated between 2004 and 2007

The subprime mortgage market grew extremely quickly between 2001 and 2007. Kiff and Mills (2007), among others, argued that this was facilitated by the development of private-label mortgage backed securities, which do not carry the kind of credit risk protection offered by government-sponsored enterprises. Demyanyk and Hemert (2011) analysed loans that originated between 2001 and 2006 and found that, during the dramatic growth of the subprime (securitized) mortgage market, the quality of the market deteriorated dramatically. In addition, significant changes to Regulation C,

which implemented the Home Mortgage Disclosure Act (HMDA), took effect in January 2004. These changes, designed primarily to enhance the understanding of mortgage markets and assist in fair lending enforcement, increased the amount and types of public information about residential real estate lending. Because of the dramatic growth of loans and new regulations, a sub-sample that consisted of mortgages originating between 2004 and 2007 is created and ran the same regressions as Table 3 and Table 6.[11] The results are consistent with what we have found in the previous sections.

Insert Table 10 about here

6 Conclusion

The financial crisis triggered by the subprime mortgage crisis meant that an economic recession spread from the US to the rest of the world. This led us to reconsider residential mortgage defaults and foreclosures. Mortgage default behavior is complex. Correctly identifying the different types of default behaviors that borrowers engage in is not only important for mortgage lenders and investors of mortgage backed securities, but also crucial for policy makers.

This paper investigates whether heterogeneity in borrowers' time preferences as manifested in their mortgage choices correlates with their default decision. investigates whether heterogeneity in borrowers' time preferences as manifested in their mortgage choices correlates with their default decision. Results indicate that present-biased borrowers who select back-loaded mortgages are more likely to default than dynamically consistent borrowers. In particular, naïve borrowers with present-biased preferences, who are more likely to select interest-only loans, default earlier than borrowers of other types of loans. If borrowers have present-biased preferences or suffer from short-term temptations and are aware of the consequences (termed as 'sophisticated' as opposed to 'naïve'), then it is likely they will prefer to refrain from the temptation and behave more rationally. The default of sophisticated borrowers follows the naïve borrowers. For dynamically-consistent borrowers, the choice of fixed-rate loans leads them to default less frequently than others. The relationship between present

[11] The sub-sample analysis of loans originated between 2004 and 2007 for four states and the financial crisis break point was also done, but the results were not reported in the paper. The results are consistent with our previous results.

bias and mortgage default is maintained when controlling for borrowers' demographics and loan characteristics.

Overall, borrowers' heterogeneous time preferences as seen in their choice of mortgage types may help to better understand mortgage default behavior, and will assist in the creation of better policies to deal with the foreclosure crisis, such as mortgage modification and mortgage contract design.

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Table 1 Negative Equity in Selected States of US

State	Negative Equity Share	Near Negative Equity Share
Nevada	56.90%	5.30%
Florida	42.10%	4.10%
Arizona	38.60%	5.10%
Georgia	35.60%	6.30%
Michigan	32.00%	4.80%
California	28.30%	4.50%
Illinois	25.40%	4.60%
Ohio	23.80%	5.70%
Maryland	22.90%	4.80%
Idaho	22.30%	5.30%

Note: This table presents the ten states with the highest levels of negative equity and near negative equity in the United States. Negative equity is often used to refer to as "underwater" or "upside down," which means that borrower owes more on their mortgage than the home is worth. In other word, the borrowers' mortgage value exceeds the property value. Negative equity can occur because of a decline in property value, an increase in mortgage debt or a combination of both. Near negative equity is when mortgages are within five percent of being in a negative equity position, which is defined by CoreLogic. From Negative Equity Summary Report of CoreLogic, Jan-2013.

Table 2 Summary Statistics of Variables: Full Sample

	Original Total	IO Loans	FIX30	ARM30
IO5	10.62%	39.77%		
IO10	16.08%	60.23%		
FIX30	36.31%		100%	
ARM30	36.99%			100%
Current Interest rate	7.001	5.969	6.984	7.790
Original Loan Balance	225143.32	312080.52	216238.08	171130.41
FICO Score	663.52	699.496	683.866	617.575
OrigLTVRatioCalc	79.150	77.176	77.187	82.502
ownerocc	84.44%	81.68%	81.36%	89.45%
low_no_doc	45.22%	60.37%	45.88%	33.62%
subprime	29.34%	8.85%	18.89%	54.38%
Duration	56.606	54.444	62.426	52.452
LOG_MHPI	5.168	5.203	5.150	5.161
Sample size	3,058,413	816,569	1,110,638	1,131,206

Note: This table presents the aggregate-level summary statistics of BlackBox dataset. The sample only include 5-year interest-only loans, 10-year interest-only loans, 30-year fix-rate loans and 30-year adjustable-rate loans. Comprarsion of the average values of variables by full sample, interest-only loans, 30-year fix-rate loans and 30-year adjustable-rate loans are presented. '*IO5'* is represetation of the 5-year interest-only loans, takes the value of one for 5-year interest-only loans and zero for others; '*IO10'* is represetation of the 10-year interest-only loans, takes the value of one for 10-year interest-only loans and zero for others; '*FIX30'* is represetation of the 30-year fix-rate loans, takes the value of one for 30-year fix-rate loans and zero for others; '*ARM30'* is represetation of the 30-year adjustable-rate loans, takes the value of one for 30-year adjustable-rate loans and zero for others; '*Original Loan Balance*' is defined as the amount of principal on the closing date of the mortgage; '*FICO Score'* refers to the Fair Issacs borrowers score at the time of loan origination. '*OrigLTVRatioCalc'* refers to the ratio of the original loan amount to the property value at loan origination; '*Ownerocc'* takes the value of one if the property type is owner occupied and zero for others; '*low_no_doc'* takes the value of one if the documentation type of the loan is low or no documentation and zero for others; *'Subprime'* equals to one if loan is subprime and zero for others; '*Duration'* is the duration of the loans in month, which is defined as the elapsed time from origination to the end of the sample period or to the first classification as being prepaid or delinquent at least 60 days; '*LOG_MHPI'* is the logarithm for quarterly FHFA house price index.

Table 3 Time Preferences and Mortgage Default: Full Sample

Variables	IO VS FIX30	ARM30 VS FIX30	IO & ARM30 VS FIX30
IO5	0.343***		0.300***
	(0.003)		(0.002)
	[1.408]		[1.349]
IO10	0.388***		0.331***
	(0.003)		(0.002)
	[1.474]		[1.393]
ARM30		0.238***	0.219***
		(0.003)	(0.003)
		[1.268]	[1.244]
ownerocc	-0.188***	-0.211***	-0.187***
	(0.003)	(0.002)	(0.002)
	[0.828]	[0.810]	[0.830]
low_no_doc	0.317***	0.262***	0.306***
	(0.003)	(0.003)	(0.002)
	[1.373]	[1.299]	[1.358]
subprime	-0.112***	-0.167***	-0.172***
	(0.004)	(0.004)	(0.003)
	[0.894]	[0.846]	[0.842]
OrigLTVRatioCalc	0.751***	0.638***	0.689***
	(0.003)	(0.003)	(0.003)
	[2.118]	[1.892]	[1.992]
log_FICO Score	-1.015***	-0.989***	-1.041***
	(0.004)	(0.004)	(0.004)
	[0.363]	[0.372]	[0.353]
log _ Original Loan Balance	-0.233***	-0.195***	-0.203***
	(0.004)	(0.003)	(0.003)
	[0.792]	[0.823]	[0.816]
LOG_MHPI	-0.436***	-0.351***	-0.398***
	(0.004)	(0.003)	(0.003)
	[0.647]	[0.704]	[0.671]
log_duration	0.613***	0.984***	0.885***
	(0.010)	(0.009)	(0.008)
	[1.846]	[2.674]	[2.422]
Observations	1,927,207	2,241,844	3,058,413
Pseudo R-Squared	0.6892	0.6504	0.6788

Note: This table shows results of logistic regression analysis for BlackBox dataset. The sample only includes 5-year interest-only loans, 10-year interest-only loans, 30-year fix-rate loans and 30-year adjustable-rate loans. The dependant varaible is ‘default; takes the value of one for default loans and zero for others. The definitions of the independent variables are shown in Table 2. State, current year and origination year fixed effects are included in the regression but not reported. Standard errors are reported in parentheses, and estimated odds ratios for Logit regression are reported in brackets.

*Significant at the 10% level;

** Significant at the 5% level;

*** Significant at the 1% level.

Table 4 Time Preferences and Mortgage Default: Four States

Panel A Logistic Regression: State of California (CA)			
Variables	IO VS FIX30	ARM30 VS FIX30	ARM30 & IO VS FIX30
IO5	0.461***		0.423***
	(0.008)		(0.007)
	[1.586]		[1.526]
IO10	0.498***		0.442***
	(0.008)		(0.007)
	[1.645]		[1.556]
ARM30		0.228***	0.160***
		(0.009)	(0.008)
		[1.256]	[1.173]
Observations	437,487	322,103	573,012
Pseudo R-Squared	0.8000	0.7900	0.8063

Panel B Logistic Regression: State of Florida (FL)			
Variables	IO VS FIX30	ARM30 VS FIX30	ARM30 & IO VS FIX30
IO5	0.258***		0.206***
	(0.010)		(0.008)
	[1.294]		[1.229]
IO10	0.328***		0.254***
	(0.011)		(0.009)
	[1.388]		[1.289]
ARM30		0.178***	0.141***
		(0.011)	(0.010)
		[1.195]	[1.151]
Observations	171,346	191,050	266,849
Pseudo R-Squared	0.7961	0.7992	0.8019

Panel C Logistic Regression: State of Arizona (AZ)			
Variables	IO VS FIX30	ARM30 VS FIX30	ARM30 & IO VS FIX30
IO5	0.365***		0.336***
	(0.0138)		(0.012)
	[1.441]		[1.399]
IO10	0.510***		0.436***
	(0.0143)		(0.013)
	[1.665]		[1.154]
ARM30		0.248***	0.190***
		(0.015)	(0.014)
		[1.281]	[1.209]
Observations	128,980	110,668	187,854
Pseudo R-Squared	0.8084	0.7917	0.8060

Panel D Logistic Regression: State of Nevada (NV)			
Variables	IO VS FIX30	ARM30 VS FIX30	ARM30 & IO VS FIX30
IO5	0.285***		0.269***
	(0.019)		(0.017)
	[1.329]		[1.308]
IO10	0.452***		0.421***
	(0.020)		(0.018)
	[1.572]		[1.523]
ARM30		0.159***	0.108***
		(0.022)	(0.019)
		[1.173]	[1.114]
Observations	75,076	52,577	103,097
Pseudo R-Squared	0.8236	0.8167	0.8241

Note: This table shows results of logistic regression analysis for four representative states, i.e., California, Florida, Arizona and Nevada. The dependant varaible is 'default; takes the value of one for default loans and zero for others. We do not report the entire list of control variables, and refer to Table 3 for the full lists. The definitions of the independent variables are shown in Table 2. State, current year and origination year fixed effects are included in the regression but not reported. Standard errors are reported in parentheses, and estimated odds ratios for Logit regression are reported in brackets.

*Significant at the 10% level;

** Significant at the 5% level;

*** Significant at the 1% level.

Table 5 Time Preferences and Mortgage Default: Financial Crisis Break Point

	IO VS FIX30	ARM30 VS FIX30	ARM30 & IO VS FIX30
Panel A Terminate before Financial Crisis			
IO5	0.135***		0.113***
	(0.009)		(0.006)
	[1.145]		[1.120]
IO10	0.086***		0.040***
	(0.010)		(0.007)
	[1.089]		[1.041]
ARM30		0.114***	0.111***
		(0.0070)	(0.007)
		[1.120]	[1.117]
Observations	398,861	623,388	768,469
Pseudo R-Squared	0.2292	0.2702	0.2457
Panel B Terminate after Financial Crisis			
IO5	0.365***		0.320***
	(0.003)		(0.002)
	[1.440]		[1.377]
IO10	0.410***		0.357***
	(0.003)		(0.003)
	[1.506]		[1.429]
ARM30		0.239***	0.205***
		(0.003)	(0.003)
		[1.270]	[1.227]
Observations	1,528,346	1,618,456	2,289,944
Pseudo R-Squared	0.6962	0.6665	0.6909

Note: This table shows results of logistic regression analysis for financial crisis break point. For simplify, here the time of financial crisis defined as the beginning of 2009. Therefore, the two parts of sample are: loans terminate before the end of 2008 and loans terminate after the beginning of 2009.The dependant variable is ‘default; takes the value of one for default loans and zero for others. We do not report the entire list of control variables, and refer to Table 3 for the full lists. The definitions of the independent variables are shown in Table 2. State, current year and origination year fixed effects are included in the regression but not reported. Standard errors are reported in parentheses, and estimated odds ratios for Logit regression are reported in brackets.

*Significant at the 10% level;

** Significant at the 5% level;

*** Significant at the 1% level.

Table 6 Summary Statistics of Variables: Propensity Score Matched Sample

	IO Loans Matched with FIX30			ARM30 Matched with FIX30			IO Loans and ARM30 Matched with FIX30		
Variables	Matched total	IO Loans	FIX30	Matched total	FIX30	ARM30	Matched total	IO loans and Arm30	FIX30
IO5	22.44%	44..88%					8.54%	17.08%	
IO10	27.56%	55.12%					13.54%	27.65%	
FIX30	50%		100%	50%	100%		50%		100%
ARM30				50%		100%	27.64%	55.28%	
Current Interest rate	6.311	5.943	6.777	7.388	7.304	7.473	6.889	6.779	6.997
Original Loan Balance	253257.42	260233.81	246281.03	174980.54	173859.90	176101.17	205232.94	204689.88	205776.01
FICO Score	694.293	694.035	694.552	644.457	644.736	644.178	673.229	672.690	673.768
OrigLTVRatioCalc	77.304	77.356	77.253	81.168	81.239	80.980	78.672	78.561	78.768
ownerocc	85.81%	85.85%	85.76%	88.33%	88.79%	87.86%	85.65%	85.38%	85.92%
low_no_doc	53.84%	53.88%	53.80%	37.70%	37.13%	38.26%	43.56%	43.21%	43.90%
subprime	11.18%	11.35%	11.01%	34.20%	34.23%	34.17%	23.42%	23.98%	22.85%
Duration	58.259	55.896	60.621	58.063	62.828	53.299	31.361	55.893	62.829
LOG_MHPI	5.183	5.202	5.165	5.154	5.138	5.171	5.164	5.176	5.151
Sample size	625,444	312,722	312,722	671,158	335,579	335,579	1,008,224	504,112	504,112

Note: This table presents the aggregate-level summary statistics of BlackBox dataset after Propenstiy Score matching. The sample only include 5-year interest-only loans, 10-year interest-only loans, 30-year fix-rate loans and 30-year adjustable-rate loans. Comprarsion of the average values of the variables by full sample, interest-only loans, 30-year fix-rate loans and 30-year adjustable-rate loans are presented. Definition of variables are the same as in Table 2.

Table 7 Time Preferences and Mortgage Default: Propensity Score Matched Sample

Variables	IO VS FIX30 (matched)	ARM30 VS FIX30 (matched)	IO & ARM30 VS FIX30 (matched)
IO5	0.401***		0.269***
	(0.005)		(0.004)
	[1.494]		[1.309]
IO10	0.370***		0.275***
	(0.005)		(0.004)
	[1.448]		[1.316]
ARM30		0.203***	0.197***
		(0.004)	(0.004)
		[1.226]	[1.217]
ownerocc	-0.229***	-0.218***	-0.237***
	(0.005)	(0.004)	(0.004)
	[0.795]	[0.804]	[0.789]
low_no_doc	0.312***	0.244***	0.281***
	(0.005)	(0.004)	(0.004)
	[1.366]	[1.276]	[1.324]
subprime	-0.138***	-0.112***	-0.147***
	(0.006)	(0.007)	(0.006)
	[0.871]	[0.894]	[0.863]
OrigLTVRatioCalc	0.745***	0.563***	0.695***
	(0.006)	(0.005)	(0.004)
	[2.107]	[1.756]	[2.003]
log_FICO Score	-0.982***	-0.829***	-1.027***
	(0.007)	(0.007)	(0.006)
	[0.375]	[0.437]	[0.358]
log _ Original Loan	-0.172***	-0.158***	-0.226***
Balance	(0.006)	(0.006)	(0.005)
	[0.842]	[0.854]	[0.798]
LOG_MHPI	-0.457***	-0.367***	-0.422***
	(0.007)	(0.006)	(0.005)
	[0.633]	[0.693]	[0.656]
log_duration	0.403***	0.856***	0.827***
	(0.018)	(0.016)	(0.014)
	[1.496]	[2.353]	[2.287]
Observations	625,444	671,158	1,008,224
Pseudo R-Squared	0.6868	0.6378	0.6456

Note: This table shows results of logistic regression analysis for BlackBox dataset after Propensity Score matching. The sample only includes 5-year interest-only loans, 10-year interest-only loans, 30-year fix-rate loans and 30-year adjustable-rate loans. The dependant varaible is 'default; takes the value of one for default loans and zero for others. The definitions of the independent variables are shown in Table 2. State, current year and origination year fixed effects are included in the regression but not reported. Standard errors are reported in parentheses, and estimated odds ratios for Logit regression are reported in brackets.

*Significant at the 10% level;

** Significant at the 5% level;

*** Significant at the 1% level.

Table 8 Time Preferences and Mortgage Default: Four States of Propensity Score Matched Sample

Panel A Logistic Regression: State of California (CA)			
	IO VS FIX30 (matched)	ARM30 VS FIX30 (matched)	ARM30 & IO VS FIX30 (matched)
IO5	0.531***		0.444***
	(0.013)		(0.011)
	[1.701]		[1.559]
IO10	0.446***		0.368***
	(0.013)		(0.011)
	[1.562]		[1.445]
ARM30		0.226***	0.155***
		(0.015)	(0.013)
		[1.254]	[1.168]
Observations	120,666	89,928	156,870
Pseudo R-Squared	0.7662	0.7798	0.7548

Panel B Logistic Regression: State of Florida (FL)			
	IO VS FIX30 (matched)	ARM30 VS FIX30 (matched)	ARM30 & IO VS FIX30 (matched)
IO5	0.269***		0.185***
	(0.019)		(0.014)
	[1.309]		[1.203]
IO10	0.315***		0.215***
	(0.019)		(0.015)
	[1.370]		[1.239]
ARM30		0.164***	0.125***
		(0.017)	(0.015)
		[1.179]	[1.134]
Observations	51,886	62,388	92,234
Pseudo R-Squared	0.7949	0.8027	0.7893

Panel C Logistic Regression: State of Arizona (AZ)			
	IO VS FIX30 (matched)	ARM30 VS FIX30 (matched)	ARM30 & IO VS FIX30 (matched)
IO5	0.361***		0.263
	(0.0248)		(0.021)
	[1.435]		[1.301]
IO10	0.445***		0.335
	(0.025)		(0.022)
	[1.561]		[1.398]
ARM30		0.206***	0.138
		(0.026)	(0.024)
		[1.229]	[1.147]
Observations	34,012	29,700	43,448
Pseudo R-Squared	0.7917	0.7807	0.7724

Panel D Logistic Regression: State of Nevada (NV)			
	IO VS FIX30 (matched)	ARM30 VS FIX30 (matched)	ARM30 & IO VS FIX30 (matched)
IO5	0.326***		0.247***
	(0.035)		(0.031)
	[1.385]		[1.280]
IO10	0.386***		0.300***
	(0.034)		(0.032)
	[1.471]		[1.349]
ARM30		0.147***	0.111***
		(0.038)	(0.033)
		[1.159]	[1.117]
Observations	16,732	13,234	19,452
Pseudo R-Squared	0.8099	0.8129	0.8077

Note: This table shows results of logistic regression analysis for four representative states after Propensity Score matching, i.e., California, Florida, Arizona and Nevada. The dependant varaible is 'default; takes the value of one for default loans and zero for others. We do not report the entire list of control variables, and refer to Table 3 for the full lists. The definitions of the independent variables are shown in Table 2. State, current year and origination year fixed effects are included in the regression but not reported. Standard errors are reported in parentheses, and estimated odds ratios for Logit regression are reported in brackets.
*Significant at the 10% level;
** Significant at the 5% level;
*** Significant at the 1% level.

Table 9 Time Preferences and Mortgage Default: Financial Crisis Break Point of Propensity Score Matched Sample

	IO VS FIX30	ARM30 VS FIX30	ARM30 & IO VS FIX30
Panel A Terminate before Financial Crisis			
IO5	0.186***		0.077***
	(0.018)		(0.012)
	[1.204]		[1.080]
IO10	0.075***		-0.027
	(0.020)		(0.015)
	[1.078]		[0.974]
ARM30		0.080***	0.062***
		(0.012)	(0.012)
		[1.083]	[1.064]
Observations	96,862	167,070	203,072
Pseudo R-Squared	0.1960	0.2664	0.2624
Panel B Terminate after Financial Crisis			
IO5	0.414***		0.296***
	(0.005)		(0.004)
	[1.513]		[1.345]
IO10	0.389***		0.303***
	(0.005)		(0.004)
	[1.475]		[1.354]
ARM30		0.210***	0.200***
		(0.005)	(0.004)
			[1.221]
Observations	512,398	492,250	789,000
Pseudo R-Squared	0.6962	0.6471	0.6603

Note: This table shows results of logistic regression analysis for financial crisis break point after Propensity Score matching. For simplify, here the time of financial crisis defined as the beginning of 2009. Therefore, the two parts of sample are: loans terminate before the end of 2008 and loans terminate after the beginning of 2009.The dependant variable is ‘default; takes the value of one for default loans and zero for others. We do not report the entire list of control variables, and refer to Table 3 for the full lists. The definitions of the independent variables are shown in Table 2. State, current year and origination year fixed effects are included in the regression but not reported. Standard errors are reported in parentheses, and estimated odds ratios for Logit regression are reported in brackets.

*Significant at the 10% level;

** Significant at the 5% level;

*** Significant at the 1% level.

Table 10 Time Preferences and Mortgage Default: Loans Originated between 2004 and 2007

	Original Sample			Matched Sample		
Variables	IO VS FIX30	ARM30 VS FIX30	IO & ARM30 VS FIX30	IO VS FIX30	ARM30 VS FIX30	IO & ARM30 VS FIX30
IO5	0.350***		0.303***	0.371***		0.267***
	(0.003)		(0.003)	(0.005)		(0.004)
	[1.419]		[1.354]	[1.449]		[1.306]
IO10	0.389***		0.328***	0.358***		0.284***
	(0.003)		(0.003)	(0.005)		(0.004)
	[1.476]		[1.389]	[1.430]		[1.328]
ARM30		0.224***	0.196***		0.196***	0.172***
		(0.003)	(0.003)		(0.005)	(0.004)
		[1.268]	[1.217]		[1.216]	[1.188]
ownerocc	-0.185***	-0.215***	-0.188***	-0.240***	-0.232***	-0.249***
	(0.003)	(0.003)	(0.002)	(0.005)	(0.005)	(0.004)
	[0.831]	[0.810]	[0.829]	[0.786]	[0.793]	[0.780]
low_no_doc	0.326***	0.267***	0.312***	0.315***	0.255***	0.295***
	(0.003)	(0.003)	(0.002)	(0.005)	(0.005)	(0.004)
	[1.385]	[1.299]	[1.366]	[1.370]	[1.290]	[1.343]
subprime	-0.120***	-0.179***	-0.182***	-0.135***	-0.134***	-0.151***
	(0.004)	(0.004)	(0.003)	(0.006)	(0.007)	(0.006)
	[0.887]	[0.846]	[0.833]	[0.874]	[0.875]	[0.860]
OrigLTVRatioCalc	0.740***	0.641***	0.688***	0.733***	0.567***	0.729***
	(0.004)	(0.003)	(0.003)	(0.006)	(0.005)	(0.005)
	[2.096]	[1.892]	[1.989]	[2.081]	[1.762]	[2.072]
log_FICO Score	-1.019***	-0.995***	-1.048***	-0.984***	-0.859***	-1.038***
	(0.005)	(0.005)	(0.004)	(0.007)	(0.008)	(0.007)
	[0.361]	[0.372]	[0.351]	[0.374]	[0.423]	[0.354]
log _ Original Loan Balance	-0.206***	-0.159***	-0.175***	-0.154***	-0.134***	-0.184***
	(0.004)	(0.003)	(0.003)	(0.006)	(0.006)	(0.005)
	[0.814]	[0.823]	[0.840]	[0.858]	[0.875]	[0.832]
LOG_MHPI	-0.428***	-0.340***	-0.392***	-0.443***	-0.347***	-0.393***
	(0.004)	(0.004)	(0.003)	(0.007)	(0.006)	(0.006)
	[0.652]	[0.704]	[0.676]	[0.642]	[0.707]	[0.675]

Continued						
	Original Sample			Matched Sample		
Variables	IO VS FIX30	ARM30 VS FIX30	IO & ARM30 VS FIX30	IO VS FIX30	ARM30 VS FIX30	IO & ARM30 VS FIX30
log_duration	0.456***	0.749***	0.683***	0.414***	0.602***	0.585***
	(0.011)	(0.010)	(0.008)	(0.019)	(0.017)	(0.015)
	[1.578]	[2.674]	[1.980]	[1.512]	[1.825]	[1.795]
Observations	1,567,667	1,654,772	2,447,692	571,868	504,368	770,614
Pseudo R-Squared	0.6903	0.6460	0.6762	0.6831	0.6337	0.6510

Note: This table shows results of logistic regression analysis for BlackBox dataset with loans originated between 2004 and 2007: both before and after Propensity Score matching. The sample only includes 5-year interest-only loans, 10-year interest-only loans, 30-year fix-rate loans and 30-year adjustable-rate loans. The dependant varaible is 'default; takes the value of one for default loans and zero for others. The definitions of the independent variables are shown in Table 2. State, current year and origination year fixed effects are included in the regression but not reported. Standard errors are reported in parentheses, and estimated odds ratios for Logit regression are reported in brackets.

*Significant at the 10% level;

** Significant at the 5% level;

*** Significant at the 1% level.

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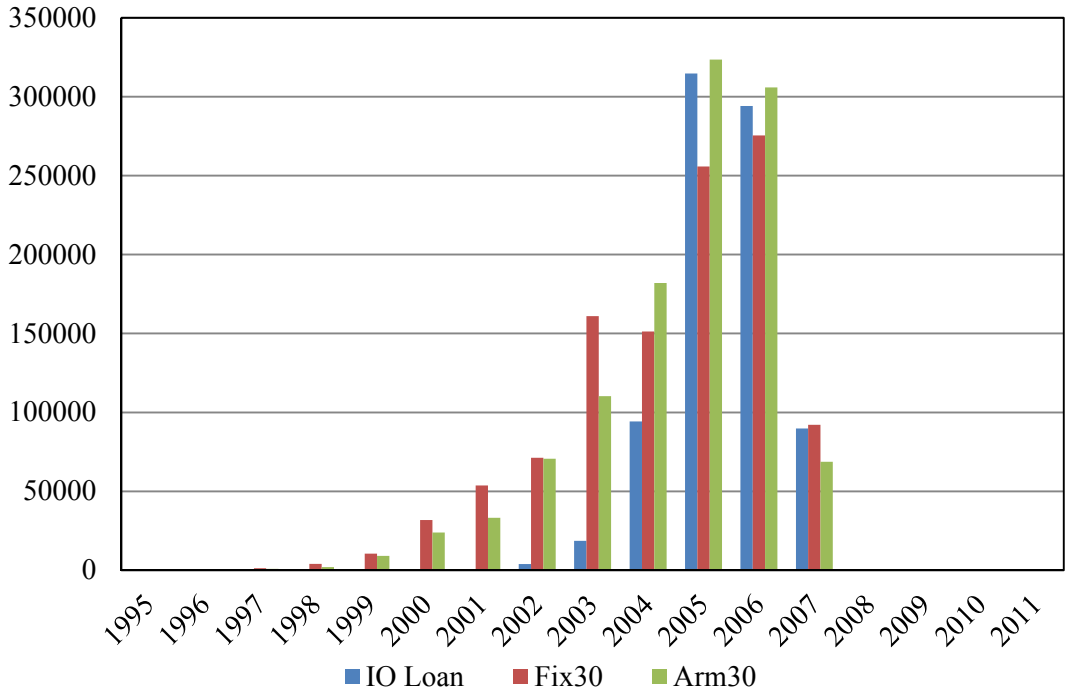
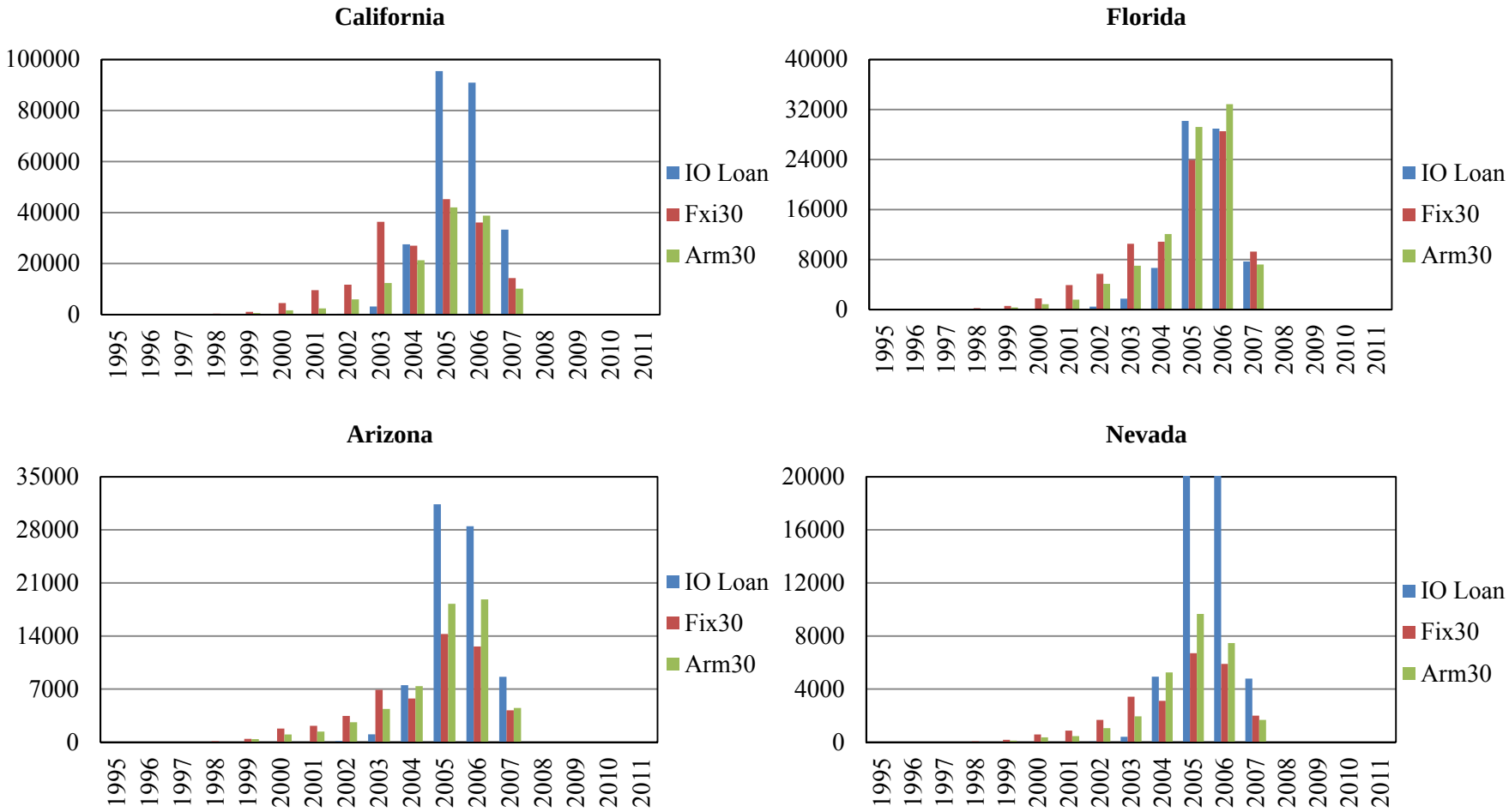
Figure 1 Frequency Distribution by Origination Year: Full Sample



Note: This figure shows the frequency distribution of all kinds of loans originations for the full sample. Y-axis measures the frequency of origination, while X-axis measures the year. Three loan types are included in this sample: interest-only loans, 30-year fixed-rate loans and 30-year adjustable-rate loans.

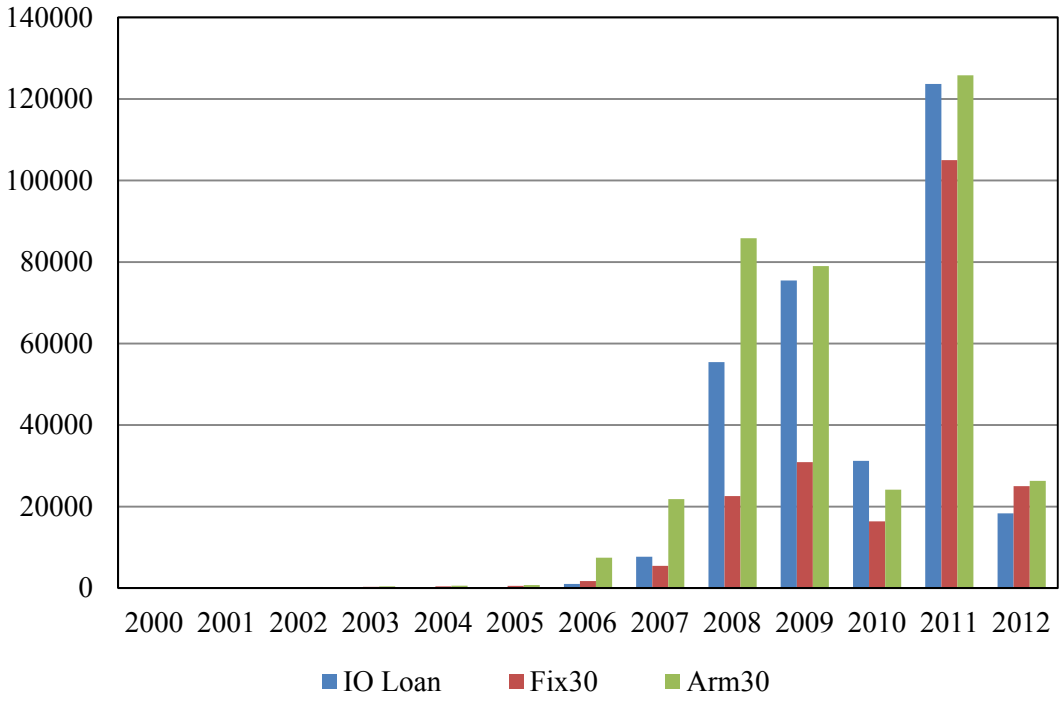
Figure 2 Frequency Distribution by Origination Year: Four States



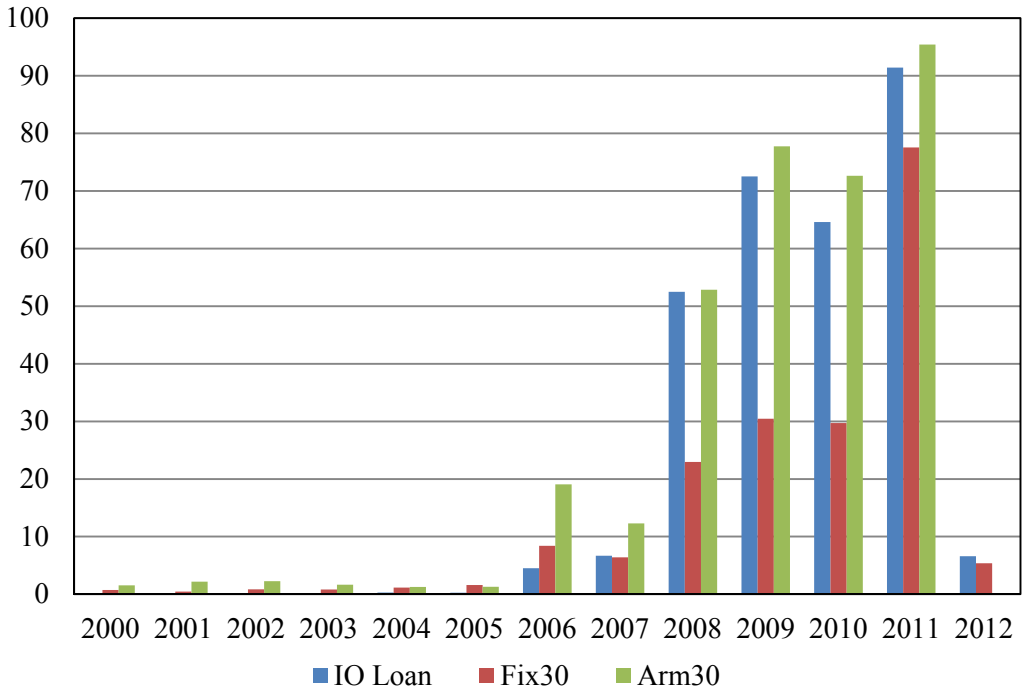
Note: This figure shows the frequency distribution of all kinds of loan originations for four states: California (CA), Florida (FL), Arizona (AZ) and Nevada (NV). Three loan types are included in this sample: interest-only loans, 30-year fixed-rate loans and 30-year adjustable-rate loans. Y-axis measures the frequency of origination, while X-axis measures the year.

Figure 3 Default Distribution over Years: Full Sample

A. Frequency Distribution of Default by Year



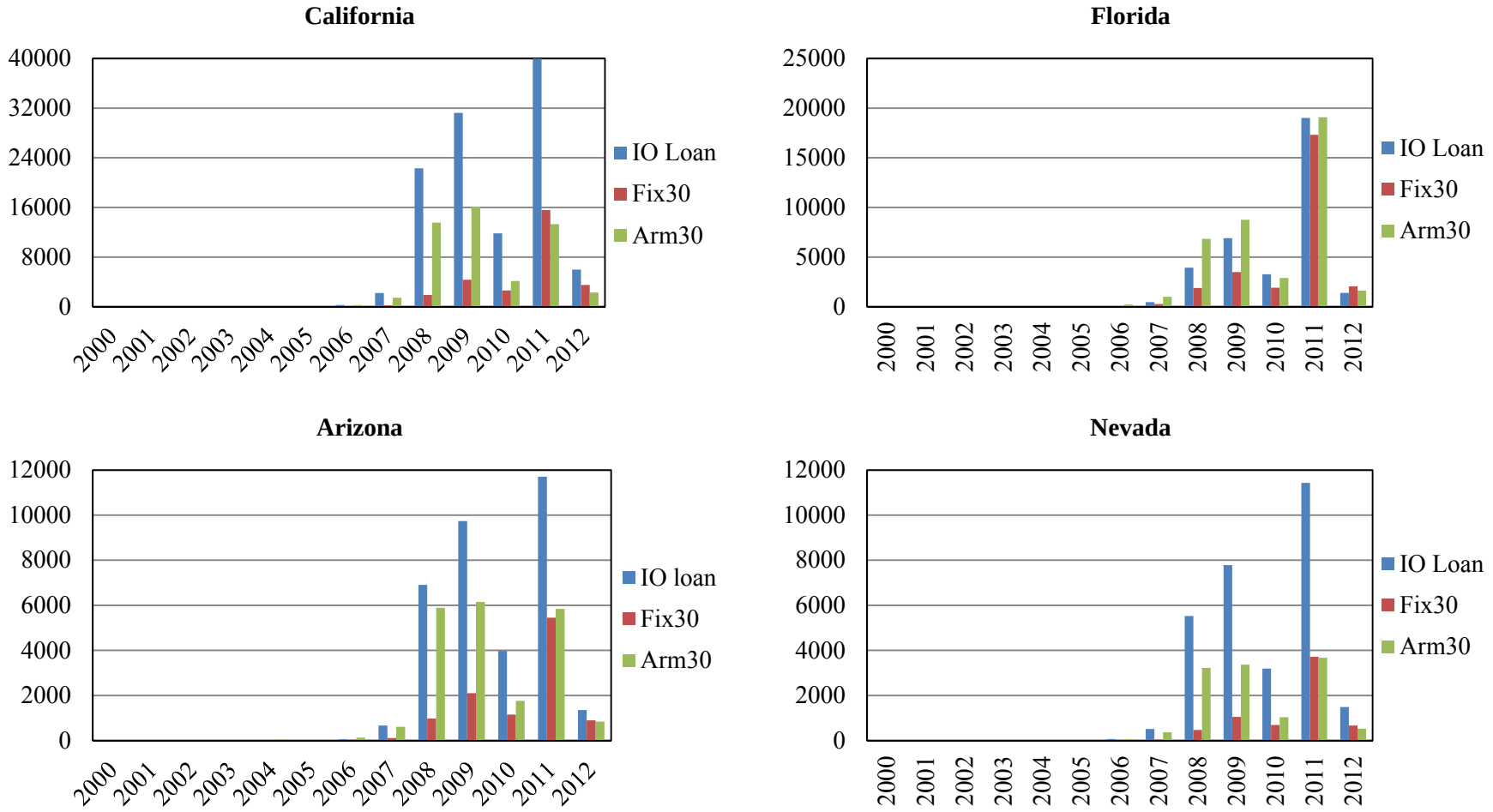
B. Percentage of Default by Year



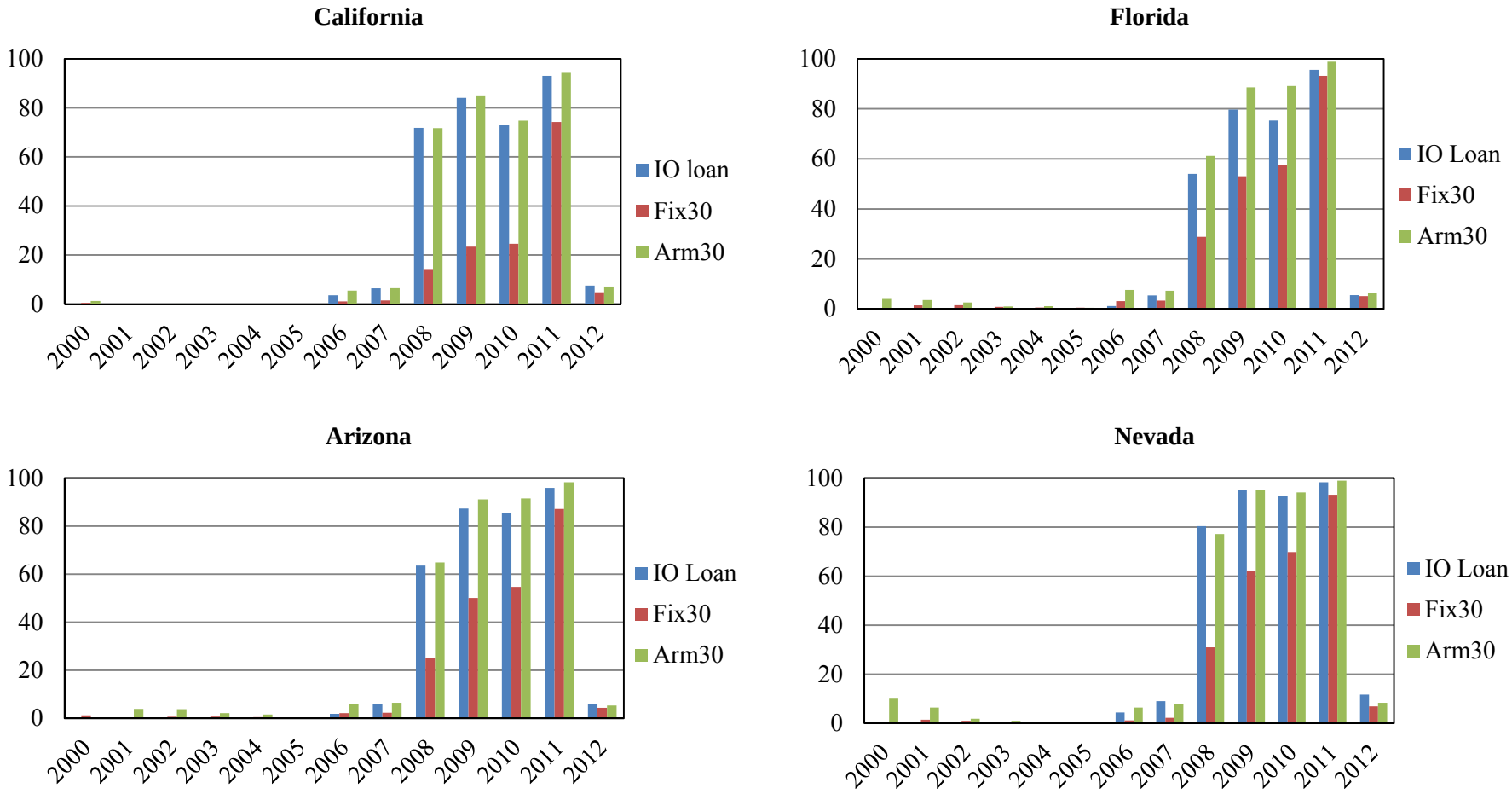
Note: This figure shows the frequency and percentage of default distribution for all kinds of loans over year. In panel A, Y-axis measures the frequency of default loans, while X-axis measures the year. In panel B, Y-axis measures the default rate, while X-axis measures the year.

Figure 4 Default Distribution over Years: Four States

A. Frequency Distribution of Default by Year



B. Percentage of Default by Year



Note: This figure shows the default frequency and percentage distribution of all kinds of loans by year for four states: California (CA), Florida (FL), Arizona (AZ) and Nevada (NV). In panel A, Y-axis measures the frequency of default loans, while X-axis measures the year. In panel B, Y-axis measures the default rate, while X-axis measures the year.