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The Effect of Neighborhood Spillovers on Mortgage Selection *

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Abstract

In this paper we analyze how spillovers in mortgage adoption affect mortgage product choice across neighborhoods and across borrowers of different racial or ethnic groups. We use loan-level data on subprime mortgages for metropolitan areas in California and Florida during 2004 and 2005, the peak years of the subprime mortgage boom. We identify an important and statistically significant effect of spillovers, both within and across groups, on the consumers' choice of hybrid mortgage products that were popular during this period. In particular, we find that the group-specific spillover effects are strengthened by the group affiliation (race and ethnicity) of the borrower. The effects are particularly important among Hispanic and white borrowers, but not among black borrowers.

JEL Codes: G21, J15, R23, R31.

Keywords: Subprime mortgages, Hybrid mortgages, Neighborhood effects, Hispanic population.

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1 Introduction

A large literature in household finance has examined the various determinants of mortgage choice. While mortgages are complex and can differ along many dimensions, most problems of mortgage choice have been examined as a problem of household financial risk management. This is true not only for studies examining the choice between the two main product categories: namely, adjustable rate mortgages (ARM) and fixed rate mortgages (FRM) (Campbell and Cocco, 2003), but also for more complex hybrid contract types (Piskorski and Tchistyi, 2010).

In this paper, we examine the role of preference externalities in determining the choice of mortgage products. In particular, we focus on the spectacular growth of of certain non-traditional mortgage (NTM) products during the mortgage boom in the early 2000s. In particular, we focus on whether high adoption rates of subprime hybrid mortgage products at a given location affected the origination of similar products in subsequent periods. We label this phenomenon as a neighborhood spillover effect.

In addition, we examine whether the race and ethnicity of the borrower is an important driver of these spillover effects. We find the presence of a positive and significant spillover effect within different groups based on race and ethnicity of the borrower. Interestingly, the spillover effect across groups is neither positive nor always statistically significant. We argue that the difference in within-group spillover effect across the various groups is suggestive of the fact that this spillover effect is not a purely lender-driven phenomenon.

The boom in subprime mortgages in the early 2000s has been the topic of much interest and research (see GAO, 2010 for an overview). Three observations of this boom are noteworthy: First, subprime mortgages were concentrated in locations with high proportion of minorities (mainly blacks and Hispanics), even controlling for the income and credit scores of these zip codes (Mayer and Pence, 2008). Second, the preponderance of this growth in subprime originations was largely restricted to the states of California, Florida and Nevada. Finally, an overwhelming majority—over 70 percent—of subprime mortgages originated over

the 1998-2007 period were so-called short-term hybrids. Moreover, hybrid mortgages as a proportional of total subprime originations more than doubled from 31.3 percent in 1998 to 80.2 percent in 2005.[1]

Short-term hybrids are mortgage products that combine the (initial) payment stream of a fixed rate mortgage (FRM) that later resets into the payment stream of an adjustable rate mortgage (ARM).[2] Subprime mortgage products known as 2/28 and 3/27 belong to this category. Hybrid mortgages became popular in the late 1970s and early 1980s, when interest rates were at historical highs, but their popularity waned in the 1980s (Fisher and Webb, 1994). Originally developed in the jumbo segment of the market, their popularity increased for subprime mortgages for which, the ARM-leg is typically scheduled to reset every 6 months (Bhattacharya, Fabozzi, and Berliner, 2005).[3]

Clearly, short-term hybrid products are significantly complex when compared to traditional mortgage products. This adds to a widespread perception among academics and policymakers that most subprime mortgages were originations to borrowers with a lower degree of financial sophistication and therefore less likely to have full knowledge and understanding of the terms and conditions in their mortgage contracts. Several studies supporting this view have attributed these phenomena to the confusion about mortgage terms (Bucks and Pence, 2008), the lack of financial literacy among borrowers (Gerardi, Goette, and Stephan, 2010) and even the lack of proper disclosure of mortgage costs (Lacko and Pappalardo, 2007). More importantly, these findings also note that numerical and cognitive ability does not always systematically predict riskier mortgage choices. Therefore, at least on the borrower side, it remains an open question as to why so many subprime originations were in the form of hybrid products, whose share expanded at such a rapid pace.

[1] We source this data from Corelogic Loanperformance.

[2] The 2/28 is a 30-year mortgage product that comprises an initial FRM for two years followed by an ARM for 28 years. The 3/27 is defined analogously.

[3] Arguably, this is a key difference between subprime hybrids and prime hybrids such as the 3/1, 5/1 and 7/1 mortgages, wherein the ARM-leg of the mortgage resets on an annual basis. Subprime hybrids reset at shorter maturities because they were designed to reduce lender exposure to long term contracts. Repeated resets were intended to force the borrower into refinancing the mortgage (see Gorton, 2008, for details).

Several explanations have been offered for the rapid expansion of short term hybrids. Bhattacharya, Fabozzi, and Berliner (2005) note that the growth of hybrids is often attributed to a sharp increase in the steepness of the yield curve around 2002.[4] The demand for hybrids was also sustained by the strong growth in home prices since 2003 and the declining affordability of home seekers—some of whom used these NTMs to expand their home-buying power (Agnell and Rowley, 2006). Studies of the subprime market have also noted that a segmentation of the mortgage market in terms of racial and ethnic differences resulted in part because lenders specialized across neighborhoods and marketed certain types of mortgage products more aggressively to minority borrowers, placing them at a higher risk of obtaining subprime loans (Bocian, Ernst, and Li 2006, 2008; Reid and Laderman 2009). While there is strong evidence in favor of each of the explanations described above, they do not fully reconcile the observed evidence of poor financial sophistication of subprime borrowers with the rapid expansion of hybrid mortgages.

In this paper, we seek to explain the rapid growth in short term hybrids among subprime originations in terms of a spillover effect.[5] Using loan-level data on subprime mortgage originations, we find that the probability of originating a hybrid product increases with the share of hybrids originated (as a proportion of total originations) at the same location in the previous period. Put differently, we find evidence for a positive and significant neighborhood spillover effect. In addition, we find that this neighborhood spillover effect is always strictly positive and significant for borrowers within a given group demarcated either by the borrower's race or by his or her ethnicity. In contrast, the effect is neither positive nor always statistically significant for borrowers across groups. In particular, our results show that the neighborhood spillover effect is significantly greater for white and Hispanic borrowers than for black borrowers.

[4]The 10-year/2-year spread that averaged -22 basis points in 2000 increased to an average in excess of 200 basis points around 2002. This raised the appeal of hybrid products making home buying more affordable. The borrowers attain a security of fixed payment rates for a short period of 2-3 years at rates significantly lower than those of 30-year fixed-rate mortgages.

[5]Again, we emphasize that this is perhaps not the only reason behind the expansion of NTMs in subprime mortgage. However, as we demonstrate below, there is strong evidence in support of this phenomenon.

These results may be explained, alternatively, in terms of the phenomenon described in Agnell and Rowley (2006). Aggressive lenders targeting unsuspecting and predominantly minority households would also explain why the spillover effect is positive for borrowers within groups but not across groups. However, it is unlikely that this is the whole story. Since lenders' profit maximization goals are independent of race, there is no reason a priori to believe that lenders would choose to target households of some groups but not others. Stated differently, pure profit maximization motives hardly imply significant differences in the spillover effect across groups. The evidence that the spillover effects vary across groups points to the fact that borrower demand plays a significant role in the spillover effect.

There are several strands of literature that describe the phenomenon observed in our study. The earliest mention of the spatial concentration of economic activity and related knowledge spillovers and information flows has been attributed to Marshall (1920). More recently, George and Waldfogel (2003) and Waldfogel (2003, 2005) have shown how product choice and product diversification can be influenced by the size of the local minority population. The effects of agglomeration on consumer activity can be robust especially in environments where language and ethnic barriers form impediments. In particular, proximity to neighborhoods with a high concentration of homeowners of the same ethnicity facilitates the diffusion of knowledge of the mortgage application process, likely through expanded word-of-mouth networks as well as local civic or religious organizations. This feature has been shown to be critical for Hispanic households facing mortgage and housing decisions (see Haurin and Rosenthal, 2009, and references therein). In addition, Haurin and Rosenthal (2009) also point to peer group and role model effects that might influence a household's financial decision. Although our study does not distinguish between the effects of agglomeration and role model effects, these effects bear relevance for our results.

At the heart of these explanations is the phenomenon, referred to in the literature as *observational* or *social* learning, whereby the actions of one set of economic decision makers influence the purchases and financial decisions of others. This form of observational learning

can dominate private information about products and contracts leading consumers to act as if they are in an *informational cascade* (Bikhchandani, Hirshleifer, and Welch, 1998). Since empirical evidence on observational learning is significantly difficult to obtain, efforts in the literature have concentrated on randomized natural field experiments as in Cai, Chen, Fang, and Zhou (2009). While our study alludes to the fact that individual borrower decisions could be affected by observing others' choices, it cannot establish the existence of observational learning.

Our study uses a discrete choice model to determine how individual and neighborhood characteristics determine the choice of mortgage contracts. There are several studies that analyze mortgage choice in this framework. Using micro data from the 1983 Survey of Consumer Finances, Gabriel and Rosenthal (1991) suggest that minority households are significantly less likely to obtain conventional home loans than white borrowers, even after controlling for proxies of default risk. Hendershott, LaFayette, and Haurin (1997) in turn analyzed the joint choice of loan-to-value ratios and mortgage type using data from the 1984 American Housing Survey. They focused on the role of Federal Housing Administration (FHA) financing in easing mortgage qualification constraints. The authors did not analyze credit or demographic factors. Pennington-Cross and Nichols (2000) introduced borrower credit history in the analysis, matching data reported under the Home Mortgage Disclosure Act (HMDA) with data from a credit bureau. They found that credit history plays an important role in the FHA vs. conventional choice, and while they did not find that black borrowers were less likely to select FHA-mortgages than other borrowers, the authors found that Hispanics were more likely to use FHA than white borrowers.

More recent studies of mortgage choice have focused on the choice of prime vs. nonprime mortgages. Courchane, Surette, and Zorn (2004) used a survey of prime and *subprime borrowers* (defined as those with higher credit risk) to study whether subprime borrowers were being channeled to the subprime segment. They found that subprime borrowers were less knowledgable about the mortgage process and were less likely to search for the best mortgage

rates. Their results indicate that in addition to typical underwriting factors, Hispanic ethnicity and age are important determinants of market segmentation, and that Hispanic borrowers and older borrowers may disproportionately find themselves in the subprime market.

To the best of our knowledge, ours is one of the first studies to analyze mortgage product choice during the recent subprime lending boom. The study closest in spirit to ours is Reid and Laderman (2009), which also analyzes mortgage choice during the same period, but their focus is foreclosure outcomes across racial or ethnic groups and they do not consider neighborhood and spillover effects on the choice of mortgage products. Reid and Laderman (2009) use HMDA data merged with a proprietary dataset on loan performance collect by LPS Applied Analytics, Inc., for the period 2004 to 2006 for California.[6] They examine the choice between four mortgage products: prime fixed rate mortgages, prime adjustable rate mortgages, subprime fixed rate mortgages, and subprime adjustable rate mortgages. In the choice decision, the authors emphasize the role of different market channels. Their results indicate that black and Hispanic borrowers in California had access to markedly different markets than comparable white borrowers and this market segmentation played an important role in their likelihood of receiving a higher-priced loan. The authors also study the differences in foreclosure rates across racial or ethnic groups and find that after controlling for the choice of mortgage product, the differences in foreclosures fall considerably, suggesting that the disparities primarily result from differential access to lending markets.

In the next section 2, we describe the data sets used in the analysis. In section 3 we present the methodology. We discuss the summary statistics in section 4 and the results in section 5, and we provide concluding comments in section 6.

[6]The LPS dataset is also referred to as the *McDash data*, since McDash Analytics was the original compiler.

2 Data

In this study we use two sources of mortgage data. We combine data reported under HMDA with data on private-label asset backed securities from Core Logic Information Solutions, Inc. (CL), for California and Florida during 2004 and 2005.

The HMDA data contain limited information on the characteristics of the loan, including the amount, type (conventional or government-backed), purpose (purchase, home improvement, or refinancing), and lien status (first or subordinate). Most of the observations correspond to loans originated in metropolitan areas, as only lenders with assets over a certain threshold are required to report data on the loans they originate or purchase. The data set also contains information on the race and ethnicity of the applicants. In this study we focus on Hispanics, who can be of any race. HMDA data do not include information about the credit-risk profile of the borrowers other than their income. Finally, the data also contain information on the property associated with the mortgage, such as whether it is owner occupied and the Census tract and metropolitan area of its location.

The CL data contain extensive information on the characteristics of loans that were securitized in private-label subprime pools. The information on loan characteristics include, among other variables, the interest rate, the mortgage product type, the terms of the loan (including information on amortization terms and the reset periods of adjustable rate mortgages), and whether the loan has a prepayment penalty or the borrower has been required to acquire private mortgage insurance. The CL data also provide information on the borrower, including the FICO credit score, the borrower's reported debt-to-income ratio, and the extent to which the borrower's income was documented. The information on the property includes the sale or appraised price, the type of property, and the state and ZIP code of its location.

The HMDA and CL data sets were matched following the algorithm developed by Haughwout, Mayer, and Tracy (2009). The procedure uses the loan originator names, the loan amounts, as well as the dates of originations, and also involves associating ZIP codes with

Census tracts to establish search areas of HMDA loans for each loan in CL.

3 Methodology

3.1 Model of mortgage choice

In this section, we describe our methodology to examine determinants of the borrower's choice of hybrid mortgage products. As described above, although hybrids (such as the 3/1, 5/1 and 7/1) have been in existence in other segments of the U.S. mortgage market, we focus our attention on the 2/28 and 3/27 hybrid mortgage products that were unique to the subprime product universe.

We model the mortgage choice problem with a standard probit regression. We assume that the difference between the benefit and cost of adopting a hybrid product over all other product types can be denoted in terms of an unobserved variable y^*. Therefore the net utility of adopting a hybrid product for borrower i at Census track k in period t is described as

$$y^*_{ikt} = \mathbf{x}'_{it}\beta + \mathbf{w}'_{k,t}\delta + \gamma\zeta_{k,t-1} + u_{ikt} \tag{1}$$

where $\mathbf{x}_{it}$ is a set of contemporaneous borrower and loan characteristics, $\mathbf{w}_{k,t}$ is a set of economic and location characteristics, and $\zeta_{k,t-1}$ is a lagged scalar measure of adoption rate of hybrid products defined at the Census tract level. Following standard conventions of the index function model, we define our probit estimation procedure in terms of observable covariates

$$\Pr[y_{ikt} = 1|\mathbf{x}_{it}, \mathbf{w}_{k,t}, \zeta_{k,t-1}] = \Phi(\mathbf{x}'_{it}\beta + \mathbf{w}'_{k,t}\delta + \gamma\zeta_{k,t-1}) \tag{2}$$

where Φ denotes the standard normal cdf.

The vector $\mathbf{x}$ includes borrower and loan characteristics, including the FICO credit score, the loan-to-value ratio, the debt-to-income ratio, the loan amount, an indicator variable for whether the loan is a purchase or refinance, and an indicator variable for whether the bor-

rower's income is fully documented. Additionally, the vector includes an indicator variable, D_g, that takes the value of 1 if the borrower belongs to a given group and 0 otherwise, where the groups are given by $g = hisp(anic), black, white$, and $nonwh(ite)$. Therefore, we consider four groups based on the individual borrower's race and ethnicity, namely Hispanics, blacks, whites and non-whites, and we analyze them in two separate pairings: first, we compare whites and non-whites, and second, we compare Hispanics and blacks.

The groups are defined in terms of the race and ethnicity indicators provided in the HMDA data. The ethnicity indicator determines whether the borrower is Hispanic or not. The race indicator includes various racial groups, such as white, black, Asian, and so on. Blacks and whites are defined in terms of both the race and ethnicity variable. That is, for the purposes of our analysis, an individual is denoted as black if the ethnicity variable indicates non-Hispanic and the race variable indicates black. Whites are similarly defined as non-Hispanic whites. Finally, we define non-whites to include Hispanic or black (as defined above).

Note, therefore, that the groups Hispanic and black are mutually exclusive, as are the groups white and non-white. Note also that the two pairings of groups are not exhaustive as the sample includes individuals of other races in addition to white and black, and other non-Hispanic individuals. We do this to facilitate the comparisons in the regression analysis and to avoid the so-called dummy variable trap in the probit regressions. In the regressions, therefore, the omitted category will be individuals that do not belong to either the white or non-white groups in the first case, or to the Hispanic or black groups in the second case.

The vector $\mathbf{w}$ defines a set of economic and location characteristics, which includes an indicator variable for loans originated in Florida, the median family income of the Census tract relative to the median income of the corresponding metropolitan area, the share of the minority population in the Census tract, and variables summarizing local economic conditions such as the county-level unemployment rate and the county-level growth rate in house prices since the previous quarter.

Our focus of interest centers on the lagged measure(s) of adoption, ζ_{t-1}, showing the rate of adoption of hybrid products at the same location *in the previous period*. We define a positive effect of this measure on subsequent choice of hybrid mortgage products as evidence of *spillover*.

Let $Q_{k,t}$ denote the set of subprime originations originated at Census tract k in period t. We denote $q_{k,t}$ as an element of this set. Next, we define the subsets $Q_{k,t}^{hybrid} \subset Q_{k,t}$ as the set of hybrid mortgages among $Q_{k,t}$ and $Q_{k,t}^{g} \subset Q_{k,t}$ as the subset of subprime mortgages originated to a given group, where $g = hisp$, $black$, $white$, and $nonwh$. Using the above notation we define five measures of the adoption rate, ζ, as follows

$$Z_{k,t-1} = \frac{\#(q_{k,t-1} \in Q_{k,t-1}^{hybrid})}{\#(q_{k,t-1} \in Q_{k,t-1})} \tag{3}$$

$$Z_{g,t-1} = \frac{\#[(q_{k,t-1} \in Q_{k,t-1}^{hybrid}) \cap (q_{k,t-1} \in Q_{k,t-1}^{g})]}{\#(q_{k,t-1} \in Q_{k,t-1}^{g})}, \; g = hisp, black, white, \text{and } nonwh. \tag{4}$$

The first adoption measure, $Z_{k,t-1}$, is the fraction of all hybrid originations as a proportion of all subprime originations in a Census tract *in the previous quarter*. A positive effect of the first measure on the probability of choosing a hybrid mortgage product in the next quarter is viewed as evidence of overall spillover across all groups. Notably, this *overall spillover effect* is independent of the race or ethnicity of the borrower.

The other four adoption measures, $Z_{g,t-1}$, where $g = hisp$, $black$, $white$, and $nonwh$ are the fraction of hybrid originations to borrowers of a given group as a proportion of subprime originations *to the same borrower-group* in a Census tract in the previous quarter. Again, a positive effect of this measure on the probability of adopting a hybrid product in the subsequent period is viewed as evidence of spillover within groups. Notably, this *group spillover effect* depends on the race and ethnicity of the borrower.

3.2 Group interactions

We are interested in determining whether the group-specific spillover effects are strengthened by the group affiliation (race and ethnicity) of the borrower. Stated differently, our hypothesis is that the group spillover effect is likely to be greater within groups than across groups, especially for groups with closer social and language ties.

To capture these effect, we interact the borrower's group dummy variable, D_g, with the group adoption measures, $Z_{g,t-1}$, for the borrower's own group and with other groups as well.

This is given as follows

$$\Pr[y_{ikt} = 1|\mathbf{x}_{it}, \mathbf{w}_{k,t}, z] = \Phi(\mathbf{x}'_{it}\beta + \mathbf{w}'_{k,t}\delta + \sum_{g} \gamma_g Z_{g,t-1} + \sum_{g,g'} \eta_{g,g'} Z_{g,t-1} \times D_{g'}). \quad (5)$$

Since we are interesting in uncovering spillover effects that are demand-driven, we consider controlling additionally for the overall tract-level spillover effect, $Z_{k,t-1}$, which may reflect effects that are lender-driven

$$\Pr[y_{ikt} = 1|\mathbf{x}_{it}, \mathbf{w}_{k,t}, z] = \Phi(\mathbf{x}'_{it}\beta + \mathbf{w}'_{k,t}\delta + \gamma Z_{k,t-1} + \sum_{g} \gamma_g Z_{g,t-1} + \sum_{g,g'} \eta_{g,g'} Z_{g,t-1} \times D_{g'}). \quad (6)$$

The presence of a group spillover effect would imply a positive spillover effect for the borrower's own group but no such effect for interactions with other groups. It follows that our object of interest is the marginal effect of the interaction term, which we compute according Ai and Norton (2003) and Norton, Wang, and Ai (2004). These studies show that the sign of the coefficient for the interaction terms, $\eta_{k,g}$ and $\eta_{g,g}$, do not necessarily reflect the sign of the interaction effect. Furthermore, these authors argue that the computing average measures of marginal effects across all observations are inappropriate and instead, the marginal effect of the interaction should be computed for each observation in the sample.

Standard summary measures of marginal effects are computed by averaging the marginal effects at each observation ikt with respect to variable x, computed according to the formula

$$\frac{\partial \Pr[y_{ikt} = 1|X]}{\partial x} = \frac{\partial \Phi(X_{ikt}\beta)}{\partial x}, \tag{7}$$

for a continuous variable x, or as the discrete change in probability,

$$\frac{\Delta \Pr[y_{ikt} = 1|X]}{\Delta D} = \{ \Phi(X_{ikt}\beta)|_{D=1} - \Phi(X_{ikt}\beta)|_{D=0} \}, \tag{8}$$

for a binary variable D. In the above formulas, X_{ikt} denotes the row vector of explanatory variables evaluated at observation ikt.

Ai and Norton (2003) and Norton, Wang, and Ai (2004) propose that the marginal effect of the *interaction* of a discrete variable D with a continuous variable x, $x \times D$, be computed instead as the following cross-partial effect

$$\frac{\Delta \partial \Pr[y_{ikt} = 1|X]}{\Delta D \partial x} = \left. \frac{\partial \Phi(X_{ikt}\beta)}{\partial x} \right|_{D=1} - \left. \frac{\partial \Phi(X_{ikt}\beta)}{\partial x} \right|_{D=0}. \tag{9}$$

Ai, Norton, and Wang also propose that rather than averaging the marginal effects of the interaction, the effects be illustrated in a plot of all the observations. Standard errors of all these effects can be obtained with the delta method, as usual.

4 Summary statistics

In this section, we provide an overview and summary statistics of the merged data set. Our sample comprises of a little over 1.2 million individual first-lien mortgages originated in California and Florida from 2004:Q2 to 2005:Q4 (the initial quarter, 2004:Q1, is used in the calculation of the spillover measures). Table 1 presents the summary statistics for the entire sample of loans, the hybrid loans, and the nonhybrid loans.

The first three columns of table 1 provide the details of the entire sample of originations.

Table 1: Summary statistcis

	All mortgage products			Hybrids			Nonhybrids		
Variable	N	mean	sd	N	mean	sd	N	mean	sd
Hybrid	1,218,842	0.57	0.50	694,199	1.00	0.00	524,643	0.00	0.00
Hispanic	1,218,842	0.29	0.45	694,199	0.33	0.47	524,643	0.23	0.42
Black	1,218,842	0.08	0.27	694,199	0.10	0.30	524,643	0.06	0.24
White	1,218,842	0.42	0.49	694,199	0.37	0.48	524,643	0.48	0.50
Z_{tract}	1,109,344	0.58	0.19	628,561	0.62	0.17	480,783	0.54	0.20
Z_{hisp}	951,798	0.65	0.28	556,635	0.67	0.26	395,163	0.62	0.30
Z_{black}	626,757	0.68	0.34	380,528	0.70	0.32	246,229	0.66	0.35
Z_{white}	1,062,822	0.56	0.26	600,147	0.59	0.25	462,675	0.51	0.26
Z_{nonwh}	999,182	0.65	0.26	582,081	0.67	0.24	417,101	0.62	0.28
Rate differential	1,218,842	0.56	1.51	694,199	1.07	1.09	524,643	-0.11	1.71
Loan-to-value ratio (%)	1,218,842	76.50	12.95	694,199	79.39	11.14	524,643	72.69	14.13
Debt-to-income ratio (%)	1,218,842	26.98	20.02	694,199	31.29	19.08	524,643	21.28	19.80
Borrower income (thou.)	1,166,573	101.20	108.94	678,700	89.57	85.34	487,873	117.38	133.41
Loan amount (thou.)	1,218,842	300.01	194.08	694,199	267.49	143.57	524,643	343.04	238.71
Full documentation	1,218,842	0.46	0.50	694,199	0.51	0.50	524,643	0.38	0.49
Refinance	1,218,842	0.58	0.49	694,199	0.54	0.50	524,643	0.64	0.48
FICO	1,218,842	651.90	70.20	694,199	627.42	64.68	524,643	684.30	63.81
Yield curve (%)	1,218,842	2.16	1.33	694,199	2.25	1.32	524,643	2.05	1.34
Florida	1,218,842	0.31	0.46	694,199	0.33	0.47	524,643	0.28	0.45
Tract income/MSA income (%)	1,218,417	94.67	35.47	693,999	90.20	31.44	524,418	100.59	39.41
Tract minority (%)	1,218,582	46.65	27.97	694,090	49.43	28.10	524,492	42.97	27.38
House price growth (%)	1,108,884	5.99	1.99	628,191	6.07	1.97	480,693	5.87	2.02
Unemployment (%)	1,110,326	5.52	1.67	628,996	5.60	1.74	481,330	5.41	1.58

Hybrid is an indicator that takes the value of 1 if the origination is a 2/28 or 3/27 mortgage.
Z_{tract} is the count of hybrid products as share of all mortgages at the Census tract level. Z_g is the count of hybrid products for individuals of group $g = hisp(anic), black, white, nonwh(ite)$ as share of all mortgages for that group at the Census tract level.
Full documentation is an indicator that takes the value of 1 if the origination was fully documented.
Refinance is an indicator for whether the origination was a refinance.
Florida is an indicator for mortgages originated in Florida.
Tract income/MSA income is the Census tract median family income relative to metropolitan median family income.
Tract minority is the Census tract share of nonwhite population.
House price growth is the quarter-to-quarter growth in the CoreLogic county-level house price index computed at the end-of-period quarter of origination.
Unemployment is the county-level unemployment rate for the end-of-period quarter of origination.
Rate differential is the difference between the closing rate on the mortgage contract and the prime fixed rate for the month of origination.
Yield curve is the spread between the yield on the 30-year and the six-month Treasury bill.

The average loan amount is around $300,000 dollars. The mean FICO score is around 650 and the mean loan-to-value ratio at 76.5% is less than the 80% required on conventional mortgages without private mortgage insurance. More than half (58%) of the originations are refinances and little less than half (47%) of the loans provide full documentation on the loan application. For the purposes of this study it is important to note that about 57% of originations in our sample are hybrid products and 29% of originations are to Hispanic households, while only 8% of all originations are to black households and about 42% are to originations to white borrowers. On average, over the sample period the rates of adoption of hybrid products by Census tract are very similar across groups. The rate of adoption among Hispanics is 65% while the rate of adoption for black borrowers is 68%, but it is lower for white borrowers at 56%.

From the table we can also compare hybrid originations with originations of other (non-hybrid) products. Notably, 33% of hybrid products are originated to Hispanic borrowers whereas the share of non-hybrids among Hispanics is only 23%. About 10% of hybrid products are originations to black borrowers whereas the share of non-hybrids among black borrowers is only 6%.

Originations of hybrid products have a significantly lower FICO scores on average—there is almost a 60 point difference in the mean scores of hybrid originations vis-à-vis non-hybrid originations. In comparison with non-hybrid originations, hybrid originations have higher loan-to-value ratios and higher debt-to-income ratios. At the same time, hybrid originations also have a higher percentage of loans that are refinances or have full documentation on the mortgage. The loan amount is typically lower on hybrid originations.

Although not shown in the table, computing summary statistics for each group of borrowers separately would indicate that for hybrid mortgage originations, there is not much to distinguish between borrowers that are Hispanic with those who are non-Hispanic. Most mortgage and borrower characteristic such as FICO scores, loan-to-value ratios, debt-to-income ratios are comparable. However, Hispanic borrowers do have a smaller proportion of

loans that are refinances and have full documentation on the mortgage. Almost in the same fashion, within non-hybrid mortgage originations, there is not much distinguishing borrowers who are Hispanic from those who are non-Hispanic.

5 Results

This section discusses the results of our estimation procedure. As described in the previous section, we focus on determining the presence of a group-level spillover effect and spillovers across borrower groups. As described above, we conduct parallel analyses in two assortments of racial or ethnic groups: first, we compare whites and non-whites (defined as Hispanics or blacks), and second, a similar analysis for Hispanics and blacks. In each case, we use the full sample of data available, which includes individuals of other races, to avoid the dummy variable trap. The estimation results are presented in tables 2 through 5. The tables include the estimated probit coefficients and the average marginal effects, computed as the average across all the observations of the effects described in equations (7)–(9). Results for the first assortment of groups (white v. non-white) are shown in tables 2 and 4, whereas tables 3 and 5 report the results for the second assortment of groups (Hispanics v. blacks).

For each assortment of groups, we consider two sets of regressions. The first set of regressions, corresponding to equation (5), studies the group spillover effects without controlling for the overall, tract-level, spillover effect and uses only the group-level adoption measures, $Z_{g,t-1}$ (henceforth we refer to this as Z_g for simplicity), defined in equation (4), while the second set of regressions, corresponding to equation (6), adds the additional tract-level adoption measure, $Z_{k,t-1}$ (hencenforth we refer to this as Z_{tract} for clarity), defined in equation (3) to the groupwise adoption measures, Z_g. Tables 2 and 3 report estimation for the first case, and tables 4 and 5 report the results of the second case.

Within each set of regressions, we consider three models as shown in each of the tables. The models vary according to the covariates used in determining the choice of hybrid prod-

ucts. Model 1 includes only the group indicators and the adoption measures, along with quarterly dummy controls. Model 2 includes additionally a set of exogenous variables that includes FICO scores, the yield curve, and the following geographic characteristics: an indicator for Florida, a relative measure of Census tract income, and the Census tract minority share. Model 2 also includes house price growth and unemployment rates measured at the county level. Finally, Model 3 includes, in addition to the variables of Model 2, a set of borrower-level variables such as the loan-to-value and debt-to-income ratios, the borrower income, the loan amount, an indicator for whether the origination was with full documentation, and an indicator for whether the origination was for refinancing. The additional variables in Model 3 may be considered to be *endogenous*, in the sense that one can argue that the rate differential, loan-to-value ratio, and loan amount, for example, represent characteristics of the loan that are determined simultaneously with the choice of a hybrid mortgage, whereas the variables considered in Model 2 can be considered as *exogenous* to the choice of hybrid in that respect, and for this reason we consider Model 2 to be our preferred specification.

5.1 Standard credit risk variables

The estimated coefficients reported in each of the tables indicate that a standard set of borrower- and loan-level characteristics have the expected sign on the probability of adoption of hybrid products. For example, a higher FICO score, a higher origination amount, and a refinance origination reduce the likelihood of acquiring a hybrid product. On the other hand, a higher loan-to-value ratio, a higher debt-to-income ratio, and whether the origination has full documentation increase the probability of acquiring a hybrid. These results are consistent across all models and for all specifications.

The average marginal effects indicate that the magnitude of these effects is economically important. An increase of one standard deviation (about 70 points) in FICO scores relative to the mean (about 650 points) reduces the likelihood of acquiring a hybrid by 14 to 18

Table 2: Hybrid probit regression. Coefficients and Average Marginal Effects. White and nonwhite

	Coefficients			Average Marginal Effects		
Variables	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Z_{white}	0.5027	0.2424	0.1332	0.1911	0.0798	0.0315
Z_{nonwh}	0.3204	0.1632	0.0947	0.1260	0.0646	0.0341
White	-0.1512	-0.1267	-0.0393	-0.0586	-0.0480	-0.0194
Nonwhite	0.3506	0.1992	0.0842	0.1108	0.0733	0.0298
White $\times$ Z_{white}	0.2455	0.1354	0.0482	0.1360	0.0667	0.0257
Nonwhite $\times$ Z_{white}	-0.2639	-0.1517	-0.1046	-0.1461	-0.0707	-0.0353
White $\times$ Z_{nonwh}	-0.0627	-0.0318	-0.0331	-0.0362	-0.0243	-0.0202
Nonwhite $\times$ Z_{nonwh}	0.1048	0.1190	0.1047	0.0401	0.0409	0.0322
FICO		-0.5435	-0.5050		-0.1803	-0.1415
Yield curve		0.0533	0.0714		0.0177	0.0200
Florida		-0.0312	-0.4428		-0.0104	-0.1232
Tract income/MSA income		-0.0757	-0.0003		-0.0251	-0.0001
Tract minority		0.0062	0.0389		0.0020	0.0109
House price growth		0.0062	0.0096		0.0021	0.0027
Unemployment		0.0094	-0.0323		0.0031	-0.0091
Rate differential			0.2720			0.0762
Loan-to-value ratio			0.2967			0.0831
Debt-to-income ratio			0.1669			0.0468
Borrower income			-0.0122			-0.0034
Loan amount			-0.1003			-0.0281
Full documentation			0.0559			0.0157
Refinance			-0.6000			-0.1665
Constant	-0.2926	-0.3247	0.2796			
No. Obs.	955736	954104	914769	955736	954104	914769

The coefficients in gray are not statistically significant at the 10 percent level. All models include quarterly dummies.
The variables *FICO,Loan-to-value*, *Debt-to-income*, *Borrower income*, *Loan Amount*, *Tract Income/MSA Income*, and *Tract Minority* were standardized before entering them in the probit estimation. *Full doc*, *Refinance*, and *Florida* are indicator variables that take the value of 1 if the origination is fully documented, is a refinance, or occurs in Florida, respectively. The variables *Hispanic*, *Black*, *White*, *Nonwhite* are indicator variables that take the value of 1 if the observation corresponds to a borrower of that group, *Nonwhite* individuals can be Hispanic or black. Z_{tract} is the count of hybrid products as a share of all mortgages at the Census tract level. Z_g is the count of hybrid products as share of all mortages among individuals of group $g = hisp(anic), black, white, nonwh(ite)$ at the Census tract level.
Tract income/MSA income is the Census tract median family income relative to metropolitan median family income. *Tract minority* is the Census tract share of nonwhite population. *House price growth* is the quarter-to-quarter growth in the CoreLogic county-level house price index computed at the end-of-period quarter of origination. *Unemployment* is the county-level unemployment rate for the end-of-period quarter of origination. *Rate differential* is the difference between the closing rate on the mortgage contract and the prime fixed rate for the month of origination. *Yield curve* is the spread between the yield on the 30-year and the six-month Treasury bill.

The average marginal effect for all continuous variables x^k corresponds to $\sum_{j=1}^{N} \frac{1}{N} \frac{\partial \Phi\left(X_j \beta\right)}{\partial x^k}$, where Φ is the standard normal cdf, and X_j denotes the row vector of explanatory variables corresponding to observation j. Similarly, the average marginal effect for all binary variables x^k corresponds to $\sum_{j=1}^{N} \frac{1}{N} \{ \Phi(X_j \beta)\big|_{x^k=1} - \Phi(X_j \beta)\big|_{x^k=0} \}$. The average marginal effect of the interactions term of binary variable D and continuous variable Z is computed as $\sum_{j=1}^{N} \frac{1}{N} \{ \frac{\partial \Phi(X_j \beta)}{\partial Z}\Big|_{D=1} - \frac{\partial \Phi(X_j \beta)}{\partial Z}\Big|_{D=0} \}$. Standard errors of the marginal effects are computed using the delta method.

Table 3: Hybrid probit regression. Coefficients and Average Marginal Effects. Hispanic and black

	Coefficients			Average Marginal Effects		
Variables	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Z_{hisp}	0.3170	0.1423	0.0766	0.1289	0.0616	0.0334
Z_{black}	0.1606	0.0895	0.0598	0.0540	0.0299	0.0177
Hispanic	0.2247	0.1512	0.0253	0.0849	0.0751	0.0297
Black	0.3709	0.1312	0.0429	0.0899	0.0216	0.0093
Hispanic $\times$ Z_{hisp}	0.1301	0.1642	0.1482	0.0431	0.0517	0.0413
Black $\times$ Z_{hisp}	-0.1103	-0.0621	-0.0339	-0.0626	-0.0377	-0.0226
Hispanic $\times$ Z_{black}	-0.0693	-0.0250	-0.0150	-0.0306	-0.0125	-0.0069
Black $\times$ Z_{black}	0.0407	0.0749	0.0711	0.0173	0.0270	0.0211
FICO		-0.5280	-0.5026		-0.1752	-0.1413
Yield curve		0.0591	0.0770		0.0196	0.0216
Florida		-0.0467	-0.4226		-0.0155	-0.1185
Tract income/MSA income		-0.0825	-0.0091		-0.0274	-0.0026
Tract minority		-0.0023	0.0360		-0.0008	0.0101
House price growth		0.0049	0.0090		0.0016	0.0025
Unemployment		0.0104	-0.0288		0.0034	-0.0081
Rate differential			0.2651			0.0745
Loan-to-value ratio			0.3059			0.0860
Debt-to-income ratio			0.1583			0.0445
Borrower income			-0.0167			-0.0047
Loan amount			-0.0931			-0.0262
Full documentation			0.0545			0.0154
Refinance			-0.6090			-0.1692
Constant	-0.0702	-0.2581	0.2604			
No. Obs.	579373	579141	556680	579373	579141	556680

The coefficients in gray are not statistically significant at the 10 percent level. All models include quarterly dummies.
The variables *FICO,Loan-to-value*, *Debt-to-income*, *Borrower income*, *Loan Amount*, *Tract Income/MSA Income*, and *Tract Minority* were standardized before entering them in the probit estimation. *Full doc*, *Refinance*, and *Florida* are indicator variables that take the value of 1 if the origination is fully documented, is a refinance, or occurs in Florida, respectively. The variables *Hispanic*, *Black*, *White*, *Nonwhite* are indicator variables that take the value of 1 if the observation corresponds to a borrower of that group, *Nonwhite* individuals can be Hispanic or black. Z_{tract} is the count of hybrid products as a share of all mortgages at the Census tract level. Z_g is the count of hybrid products as share of all mortages among individuals of group $g = hisp(anic), black, white, nonwh(ite)$ at the Census tract level.
Tract income/MSA income is the Census tract median family income relative to metropolitan median family income. *Tract minority* is the Census tract share of nonwhite population. *House price growth* is the quarter-to-quarter growth in the CoreLogic county-level house price index computed at the end-of-period quarter of origination. *Unemployment* is the county-level unemployment rate for the end-of-period quarter of origination. *Rate differential* is the difference between the closing rate on the mortgage contract and the prime fixed rate for the month of origination. *Yield curve* is the spread between the yield on the 30-year and the six-month Treasury bill.

The average marginal effect for all continuous variables x^k corresponds to $\sum_{j=1}^{N} \frac{1}{N} \frac{\partial \Phi\left(X_j \beta\right)}{\partial x^k}$, where Φ is the standard normal cdf, and X_j denotes the row vector of explanatory variables corresponding to observation j. Similarly, the average marginal effect for all binary variables x^k corresponds to $\sum_{j=1}^{N} \frac{1}{N} \{ \Phi(X_j \beta)\big|_{x^k=1} - \Phi(X_j \beta)\big|_{x^k=0} \}$. The average marginal effect of the interactions term of binary variable D and continuous variable Z is computed as $\sum_{j=1}^{N} \frac{1}{N} \{ \frac{\partial \Phi(X_j \beta)}{\partial Z}\Big|_{D=1} - \frac{\partial \Phi(X_j \beta)}{\partial Z}\Big|_{D=0} \}$. Standard errors of the marginal effects are computed using the delta method.

percentage points, on average. Similarly, a one-standard deviation increase in the loan-to-value ratio (about 13 percent) relative to the mean (about 76.5 percent) increases the probability of acquiring a hybrid product by about 8 percentage points, on average. For any given specification, the effect of these covariates is similar.

5.2 Group hybrid adoption

The results indicate that membership to the different groups analyzed has an effect on the probability of choosing a hybrid mortgage, as indicated by the statistical significance of the group indicators (*White*, *Nonwhite*, *Hispanic*, and *Black*).

In the results comparing white and nonwhite borrowers, for example, the coefficient of the *White* indicator is negative and statistically significant, which shows that white borrowers are less likely to choose a hybrid relative to the omitted category (non-white, non-Hispanic, and non-black), while the coefficient on the *Nonwhite* indicator (which identifies borrowers that are Hispanic or black) is positive and also statistically significant, which reflects that Hispanic or black borrowers are more likely to choose a hybrid mortgage than non-white, non-Hispanic, and non-black borrowers.

Similarly, in the results comparing Hispanic and black borrowers separately, the results indicate that both Hispanics and blacks are more likely to choose a hybrid mortgage than the omitted category (non-Hispanics and non-blacks).

5.3 Group spillover effects

The results in tables 2 and 3 indicate that the group-specific hybrid adoption measures have a positive and statistically significant effect on the choice of hybrid products, suggesting the presence of a positive spillover effect.

In other words, on average, the origination of hybrid products responds positively to past choices of the local population. The effects are of a similar magnitude when we compare white and nonwhite borrowers (recall that nonwhite refers to Hispanic or black), as indicated

in table 2, but the effect of Hispanic adoption is larger than the effect of adoption of black borrowers, as indicated in table 3.

The adoption variables Z_g, for $g = white, nonwh(ite), hisp(anic), black$ vary between 0 and 1. Therefore, a coefficient of 0.0798 for the average marginal effect of variable Z_{white} under Model 2, in table 2, indicates that a 10 percentage-point increase in the adoption rate of hybrid products by white borrowers in a Census tract, leads on average, to an increase in the overall likelihood of acquiring a hybrid product of about 80 basis points in the subsequent period: $0.0798 \times 0.10 = 0.7980 \approx 80$bp. Under Model 2, the effect from the adoption of hybrids by nonwhites (Hispanic or blacks) is similar: the coefficient of 0.0646 on the variable Z_{nonwh} indicates an increase in the probability of hybrid choice of about 65 basis points in response to a 10 percentage-point increase in the adoption of hybrids by nonwhite borrowers. When comparing Hispanic and black borrowers separately, we notice that the effect on the overall adoption of hybrid mortgages from the adoption of hybrids among Hispanic is more than twice the magnitude of the effect from the adoption of hybrids among black borrowers. The coefficients for the average marginal effects under Model 2 for Hispanics and black borrowers in table 3 are, respectively, 0.0616 and 0.0299.

We are interested in uncovering group spillover effects that are demand-driven, hence the focus on group-specific adoption of hybrid products. One can argue, however, that any effects from the previous adoption of hybrids in the neighborhood represent actions by lenders choosing to promote hybrid products among certain borrower groups, for example, as a profit-maximizing choice to exploit differences in willingness-to-pay for hybrid loans across different groups. For this reason, we add to the list of controls, the tract-level adoption rate of hybrid products in the previous quarter, which may reflect overall effects that are lender-driven as in equation (6). The results from this approach are presented in tables 4 and 5.

When the overall tract-level hybrid adoption measure is added to the regressions, the coefficients on this variable, Z_{tract}, are positive and statistically significant, again suggesting

a spillover effect. The coefficients of the group-specific measures, Z_g, however, decrease in magnitude and become insignificant in our preferred specification (Model 2).

It should be noted that the marginal effects on the overall likelihood of tract-level and group-level adoption measures described up to this point refer to the partial effect on the probability of acquiring a hybrid product averaged across all borrowers irrespective of race or ethnicity. To understand the marginal effects on the choice of borrowers in a given group, or in other words, to illustrate own- and cross-group spillover effects, we need to study the interaction effects of the adoption measures with the group dummies, which we turn to next.

5.4 Interaction Effects

Most of the probit coefficients of the interaction terms of the group dummies and group adoption measures remain statistically significant even after including the overall adoption measure, Z_{tract}, in the regression. This is true for both of the group pairings we analyze, white v. nonwhite and Hispanic v. black, and illustrates that there are significant effects both among members of the same group and across individuals of different groups. In particular, the probit coefficients of the interaction terms in the first three columns of tables 4 and 5 indicate that, among members of the same racial or ethnic group the hybrid adoption rate in the previous quarter has a *positive* impact on the probability of hybrid choice, whereas the adoption rate of individuals of a different group has a *negative* impact on the probability of hybrid choice. This is true when we study white v. nonwhite borrowers and when we study Hispanic v. black borrowers.

The average marginal effects of most of the interaction terms are also statistically significant. However, some authors, namely Ai and Norton (2003) and Norton, Wang, and Ai (2004), have argued that computing and reporting the average of these effects across all observations may obscure interesting patterns as well as the statistical significance of these effects across different observations and suggest that one should instead plot the interaction effects of all the observations. This is because the interaction effect of two covariates in

Table 4: Hybrid probit regression. Coefficients and Average Marginal Effects. White and nonwhite

	Coefficients			Average Marginal Effects		
Variables	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Z_{white}	0.0153	0.0106	0.0078	0.0040	0.0012	-0.0043
Z_{nonwh}	-0.0332	-0.0120	-0.0019	-0.0183	0.0012	0.0042
White	-0.0991	-0.1046	-0.0273	-0.0515	-0.0472	-0.0192
Nonwhite	0.3300	0.2043	0.0893	0.0970	0.0708	0.0289
White $\times$ Z_{white}	0.0798	0.0534	0.0044	0.0449	0.0277	0.0082
Nonwhite $\times$ Z_{white}	-0.1007	-0.0763	-0.0644	-0.0493	-0.0321	-0.0184
White $\times$ Z_{nonwh}	0.0113	0.0056	-0.0130	0.0116	-0.0027	-0.0099
Nonwhite $\times$ Z_{nonwh}	-0.0548	0.0357	0.0575	-0.0210	0.0110	0.0174
Z_{tract}	1.2653	0.6663	0.3755	0.4749	0.2206	0.1051
FICO		-0.5406	-0.5040		-0.1790	-0.1411
Yield curve		0.0537	0.0728		0.0178	0.0204
Florida		-0.0514	-0.4456		-0.0170	-0.1239
Tract income/MSA income		-0.0628	0.0043		-0.0208	0.0012
Tract minority		-0.0042	0.0327		-0.0014	0.0091
House price growth		0.0038	0.0085		0.0013	0.0024
Unemployment		0.0047	-0.0338		0.0015	-0.0095
Rate differential			0.2724			0.0763
Loan-to-value ratio			0.2942			0.0824
Debt-to-income ratio			0.1667			0.0467
Borrower income			-0.0122			-0.0034
Loan amount			-0.0917			-0.0257
Full documentation			0.0553			0.0155
Refinance			-0.6001			-0.1664
Constant	-0.5448	-0.4327	0.2006			
No. Obs.	955736	954104	914769	955736	954104	914769

The coefficients in gray are not statistically significant at the 10 percent level. All models include quarterly dummies.
The variables *FICO*,*Loan-to-value*, *Debt-to-income*, *Borrower income*, *Loan Amount*, *Tract Income/MSA Income*, and *Tract Minority* were standardized before entering them in the probit estimation. *Full doc*, *Refinance*, and *Florida* are indicator variables that take the value of 1 if the origination is fully documented, is a refinance, or occurs in Florida, respectively. The variables *Hispanic*, *Black*, *White*, *Nonwhite* are indicator variables that take the value of 1 if the observation corresponds to a borrower of that group, *Nonwhite* individuals can be Hispanic or black. Z_{tract} is the count of hybrid products as a share of all mortgages at the Census tract level. Z_g is the count of hybrid products as share of all mortages among individuals of group $g = hisp(anic), black, white, nonwh(ite)$ at the Census tract level.
Tract income/MSA income is the Census tract median family income relative to metropolitan median family income. *Tract minority* is the Census tract share of nonwhite population. *House price growth* is the quarter-to-quarter growth in the CoreLogic county-level house price index computed at the end-of-period quarter of origination. *Unemployment* is the county-level unemployment rate for the end-of-period quarter of origination. *Rate differential* is the difference between the closing rate on the mortgage contract and the prime fixed rate for the month of origination. *Yield curve* is the spread between the yield on the 30-year and the six-month Treasury bill.

The average marginal effect for all continuous variables x^k corresponds to $\sum_{j=1}^{N} \frac{1}{N} \frac{\partial \Phi\left(X_j \beta\right)}{\partial x^k}$, where Φ is the standard normal cdf, and X_j denotes the row vector of explanatory variables corresponding to observation j. Similarly, the average marginal effect for all binary variables x^k corresponds to $\sum_{j=1}^{N} \frac{1}{N} \{ \Phi(X_j \beta)\big|_{x^k=1} - \Phi(X_j \beta)\big|_{x^k=0} \}$. The average marginal effect of the interactions term of binary variable D and continuous variable Z is computed as $\sum_{j=1}^{N} \frac{1}{N} \{ \frac{\partial \Phi(X_j \beta)}{\partial Z}\Big|_{D=1} - \frac{\partial \Phi(X_j \beta)}{\partial Z}\Big|_{D=0} \}$. Standard errors of the marginal effects are computed using the delta method.

Table 5: Hybrid probit regression. Coefficients and Average Marginal Effects. Hispanic and black

	Coefficients			Average Marginal Effects		
Variables	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Z_{hisp}	-0.0109	-0.0159	-0.0153	-0.0088	0.0015	0.0036
Z_{black}	-0.0003	0.0092	0.0130	-0.0070	0.0023	0.0040
Hispanic	0.2662	0.1931	0.0521	0.0719	0.0733	0.0291
Black	0.3572	0.1487	0.0555	0.0766	0.0201	0.0086
Hispanic $\times$ Z_{hisp}	-0.0154	0.0833	0.0993	-0.0023	0.0285	0.0284
Black $\times$ Z_{hisp}	-0.0744	-0.0464	-0.0257	-0.0242	-0.0237	-0.0158
Hispanic $\times$ Z_{black}	-0.0459	-0.0165	-0.0103	-0.0147	-0.0063	-0.0042
Black $\times$ Z_{black}	-0.0438	0.0243	0.0400	-0.0102	0.0097	0.0121
Z_{tract}	1.2950	0.7159	0.4343	0.4805	0.2370	0.1220
FICO		-0.5235	-0.5011		-0.1733	-0.1407
Yield curve		0.0586	0.0789		0.0194	0.0221
Florida		-0.0708	-0.4226		-0.0235	-0.1184
Tract income/MSA income		-0.0582	0.0003		-0.0193	0.0001
Tract minority		-0.0140	0.0282		-0.0046	0.0079
House price growth		0.0013	0.0073		0.0004	0.0020
Unemployment		0.0027	-0.0314		0.0009	-0.0088
Rate differential			0.2658			0.0746
Loan-to-value ratio			0.3013			0.0846
Debt-to-income ratio			0.1580			0.0444
Borrower income			-0.0165			-0.0046
Loan amount			-0.0773			-0.0217
Full documentation			0.0535			0.0151
Refinance			-0.6093			-0.1691
Constant	-0.5580	-0.4717	0.1043			
No. Obs.	579373	579141	556680	579373	579141	556680

The coefficients in gray are not statistically significant at the 10 percent level. All models include quarterly dummies.
The variables *FICO*,*Loan-to-value*, *Debt-to-income*, *Borrower income*, *Loan Amount*, *Tract Income/MSA Income*, and *Tract Minority* were standardized before entering them in the probit estimation. *Full doc*, *Refinance*, and *Florida* are indicator variables that take the value of 1 if the origination is fully documented, is a refinance, or occurs in Florida, respectively. The variables *Hispanic*, *Black*, *White*, *Nonwhite* are indicator variables that take the value of 1 if the observation corresponds to a borrower of that group, *Nonwhite* individuals can be Hispanic or black. Z_{tract} is the count of hybrid products as a share of all mortgages at the Census tract level. Z_g is the count of hybrid products as share of all mortages among individuals of group $g = hisp(anic), black, white, nonwh(ite)$ at the Census tract level.
Tract income/MSA income is the Census tract median family income relative to metropolitan median family income. *Tract minority* is the Census tract share of nonwhite population. *House price growth* is the quarter-to-quarter growth in the CoreLogic county-level house price index computed at the end-of-period quarter of origination. *Unemployment* is the county-level unemployment rate for the end-of-period quarter of origination. *Rate differential* is the difference between the closing rate on the mortgage contract and the prime fixed rate for the month of origination. *Yield curve* is the spread between the yield on the 30-year and the six-month Treasury bill.

The average marginal effect for all continuous variables x^k corresponds to $\sum_{j=1}^{N} \frac{1}{N} \frac{\partial \Phi\left(X_j \beta\right)}{\partial x^k}$, where Φ is the standard normal cdf, and X_j denotes the row vector of explanatory variables corresponding to observation j. Similarly, the average marginal effect for all binary variables x^k corresponds to $\sum_{j=1}^{N} \frac{1}{N} \{ \Phi(X_j \beta)\big|_{x^k=1} - \Phi(X_j \beta)\big|_{x^k=0} \}$. The average marginal effect of the interactions term of binary variable D and continuous variable Z is computed as $\sum_{j=1}^{N} \frac{1}{N} \{ \frac{\partial \Phi(X_j \beta)}{\partial Z}\Big|_{D=1} - \frac{\partial \Phi(X_j \beta)}{\partial Z}\Big|_{D=0} \}$. Standard errors of the marginal effects are computed using the delta method.

nonlinear models, such as the probit regression used here, is different from the marginal effect of interaction terms of linear models and depend on the values of covariates across different observations. Stated differently, the average marginal effect of the interaction term reported in the regressions in tables 2-5 do not allow us to infer how the effect of one variable (namely, the borrower's group affiliation) on the dependent variable (choice of a hybrid product) depends on the magnitude of another dependent variable (namely, the lagged adoption measure).

Therefore, following the methodology adopted in Ai and Norton (2003), we plot the interaction effect of the adoption measures, Z_g, with the borrower's race or ethnicity, D_g, alongside the predicted probability of the event (acquiring a hybrid mortgage) in figures 1–4. Alongside these plots, we also plot the the z-statistics of the interaction effect against the predict probability of hybrid choice of each observation. Needless to say, figures 1 and 2 are derived from the regressions reported in tables 2 and 3, respectively, while figures 3 and 4 are derived from the regressions reported in tables 4 and 5, respectively.

Next, we turn to the interaction effect for the group adoption measures of the fist assortment of groups (white v. nonwhite) in figure 1. The plots of the marginal interaction effects indicate a positive impact of own-group adoption (along the main diagonal of the plot matrix). And the marginal effects are statistically significant for essentially all observations. Interestingly, the plots also indicate that there is a negative impact on the hybrid choice probability from cross-group adoption and the marginal interaction effects are also statistically significant. The results are similar for the second assortment of groups (Hispanics v. blacks) in figure 2.

Furthermore, while the magnitude of the interaction effects varies across observation, the within-group interaction effect of the indicator variable for whites and the adoption of white borrowers reaches a higher level than for nonwhites in figure 1. Similarly, the own-group interaction of Hispanics reaches a higher level than for blacks in figure 2.

Considering the second assortment of racial or ethnic groups (Hispanic v. black) in figure

2, we may interpret the results as follows: The adoption rate of hybrid products among Hispanics in a given Census tract has a positive and significant effect on the likelihood that a Hispanic borrower will choose a hybrid product in the next quarter. On the other hand, the adoption rate of hybrid products among blacks in a given Census tract typically has a negative (and at times insignificant) effect on the likelihood that a Hispanic borrower will choose a hybrid product in the next quarter. Similarly, the adoption rate of hybrid products among black borrowers has a positive and significant effect on the likelihood that a black borrower will choose a hybrid product in the next quarter, while the adoption rate among Hispanics has a negative effect on the likelihood that a black borrower will choose a hybrid in the next quarter.

Analyzing figures 3 and 4, corresponding to the regressions reported in tables 4 and 5, which include the tract-level adoption rate, we notice that the addition of the tract-level adoption in the regressions reduces the variability of the marginal interaction effects, which suggests that the group effects are estimated more precisely. Generally, the magnitude of the group interaction effects declines slightly. The own-group effects remain positive and statistically significant for all groups except blacks for whom the marginal interaction effects are not statistically significant. In the first assortment of groups in figure 4 we also notice that the cross-effect of the impact on the adoption rate of nonwhites on white borrowers remains negative but is no longer statistically significant, while the negative effect of the adoption rate of whites on nonwhites remains statistically significant. Similarly, in the second assortment of groups in figure 5 the cross-group effects remain negative, but the effect of the previous adoption of black borrowers on Hispanic borrowers is no longer statistically significant, while the negative effect of the previous adoption of Hispanic borrowers on the hybrid choice probability of black borrowers remains statistically significant.

The regression results along with the evidence from the plots of the marginal interaction effects strongly suggest the presence of an overall spillover effect, and more importantly, of spillover effects within and across groups. Moreover, the variations in the spillover effect for

the individual groups also reaffirms our earlier assertion that the observed spillover effects among groups in particular cannot be a purely lender driven phenomenon.

6 Conclusion

Since the subprime mortgage crisis, a significant volume of literature has emerged examining the causes and consequences of the subprime debacle. Fewer studies have examined the emergence, growth, and rapid expansion of subprime mortgages since 2000. In this respect, the significant growth of short-term subprime hybrid products from less than 5% of all subprime mortgages originated in 2000 to almost 75% of mortgages originated in 2006 has remained a mystery to most researchers. Considering the significant evidence showing that most subprime borrowers lacked significant financial sophistication, this rapid expansion of hybrid products is even more puzzling.

In this paper we attempt to shed light on this puzzle from the perspective of the borrower. We argue that neighborhood spillover may have a significant role to play in the dissemination of hybrid products. We do not argue that this was the sole cause of expansion of subprime hybrid products during this period. Several other proximate causes—such as steepness of the yield curve, the affordability of hybrid products in an environment of rapid house price growth, aggressive lending efforts by brokers and banks in an effort to capture market share—may also be responsible in the widespread use of hybrid products in the subprime universe.

However, this study adds to this list of proximate causes, arguing that neighborhood spillover effects of product adoption may have a significant role to play as well. First, the proportion of hybrid subprime products in a given location increases the likelihood that a subprime borrower at the location will adopt a hybrid product subsequently. Notably, this effect of product adoption is independent of the race or ethnicity of the borrower. Further analysis reveals a group spillover effect that depends on the race and ethnicity of the borrower. For example, we observe a strong spillover effect on the adoption of hybrid mortgages for

Hispanics and whites in the following way: An increase in the origination of hybrid products among Hispanic and white subprime borrowers as a proportion of total hybrid products at a given location increases the likelihood that a subprime borrower who is Hispanic or white will adopt this product subsequently. Similar effects, albeit of a smaller magnitude, are obtained for black borrowers. More importantly, these effects are not observed across all groups; that is, the proportion of hybrid products among Hispanic subprime borrowers as a proportion of total hybrid products at a given location affect the likelihood that a subprime borrower who is black will adopt this product subsequently, but the adoption rate of black borrowers does not seem to affect the choices of Hispanic borrowers. Our interpretation of this result is that, while the spillover effect holds in general, the effect also holds true within a borrower's race and ethnicity but not always across different groups. Moreover, the result that this effect is stronger among Hispanics and white borrowers than for black borrowers, is suggestive of the fact that this may not be a purely lender-driven phenomenon.

While this study is a first step towards understanding the role of neighborhood spillover effects in increasing the appeal and widespread dissemination of subprime hybrid products, further analysis is needed to determine the mechanism by which this growth occurred. In this respect, we are agnostic about the exact mechanism by which these neighborhood effects determined mortgage choice. We hope that this phenomenon will merit further research in light of the evidence presented here.

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Figure 1: Marginal Effects of Interaction. White v. Nonwhite. Reduced form results

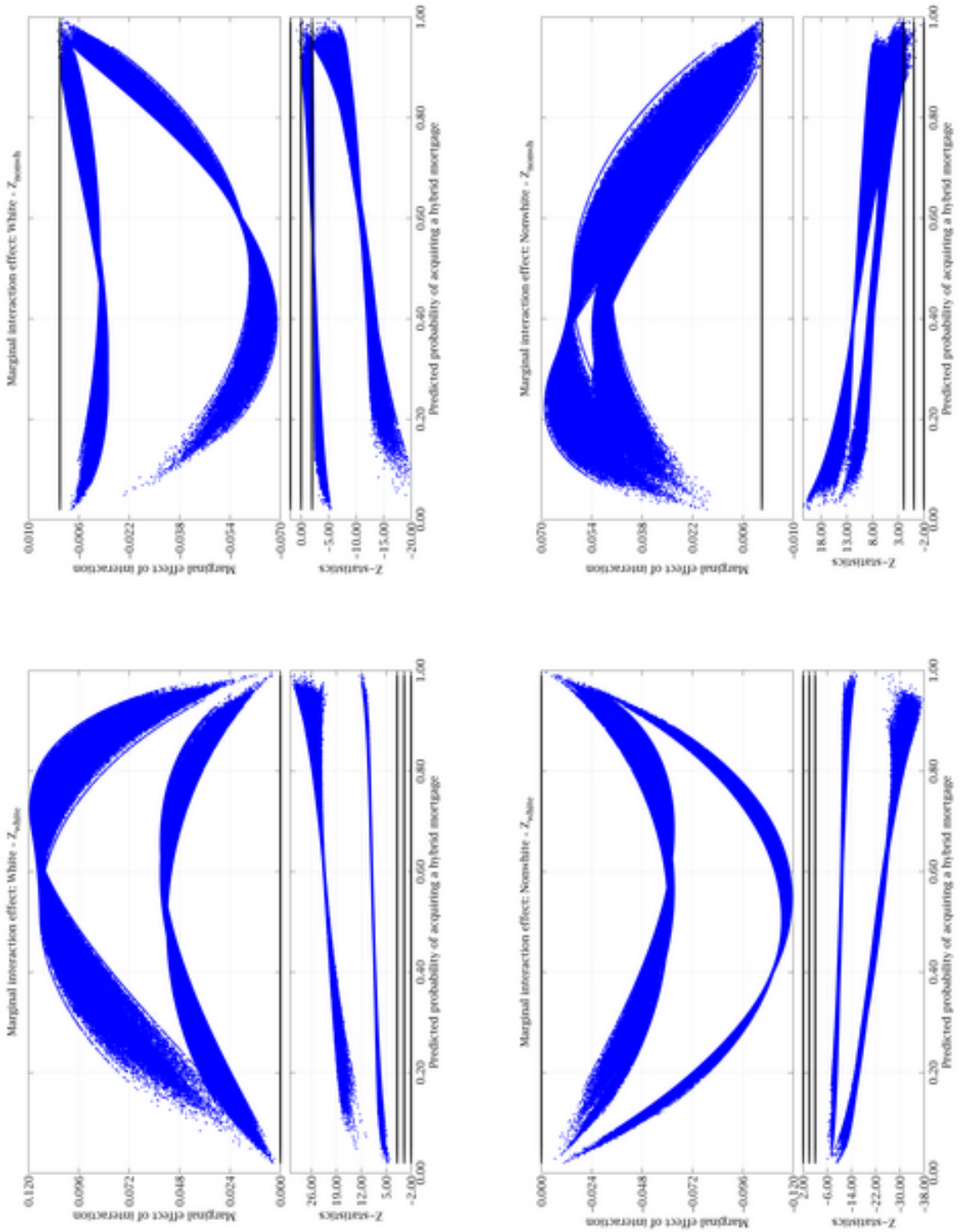

Figure 2: Marginal Effects of Interaction. Hispanic v. Black. Reduced form results

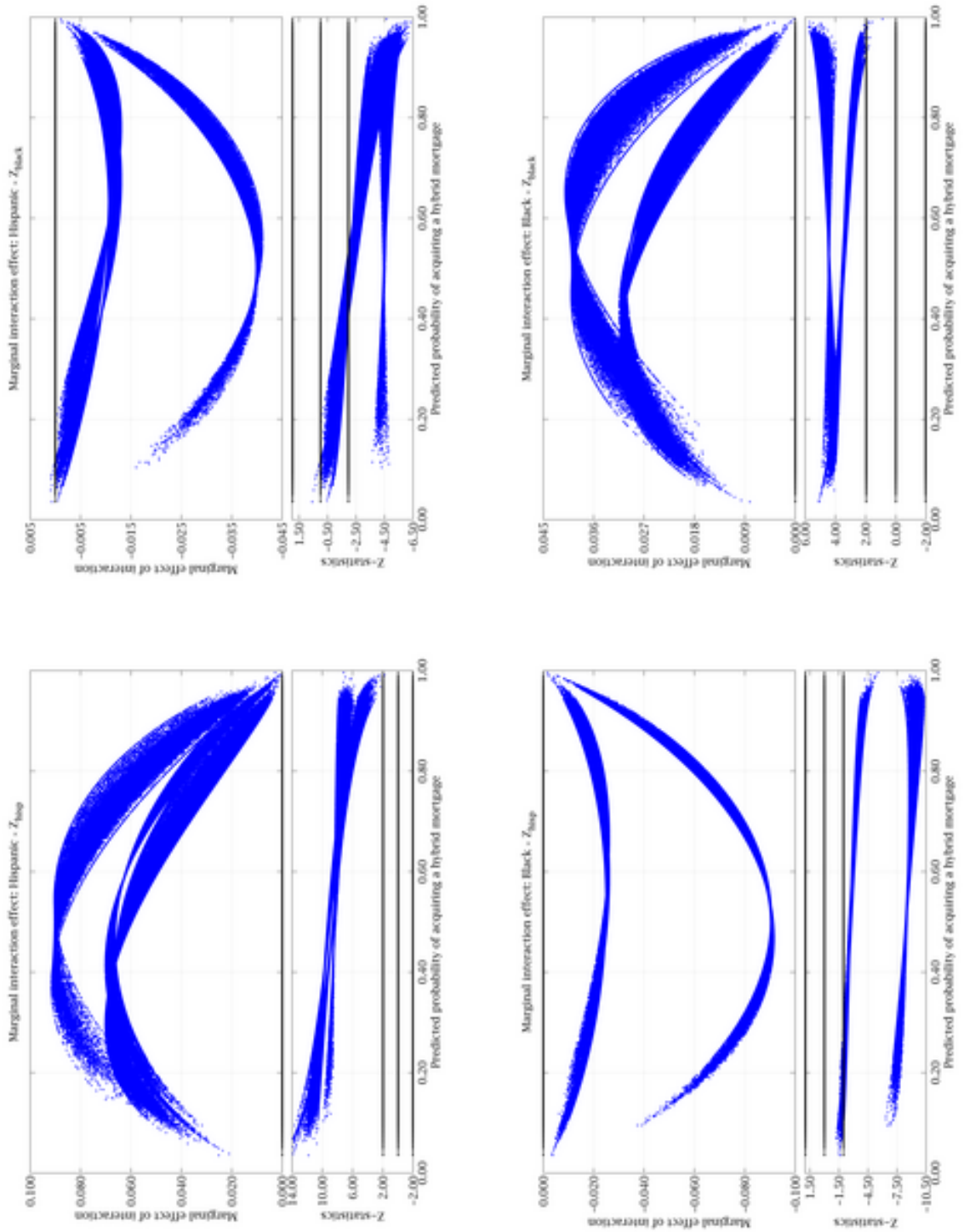

Figure 3: Marginal Effects of Interaction. White v. Nonwhite. Reduced form results with tract adoption

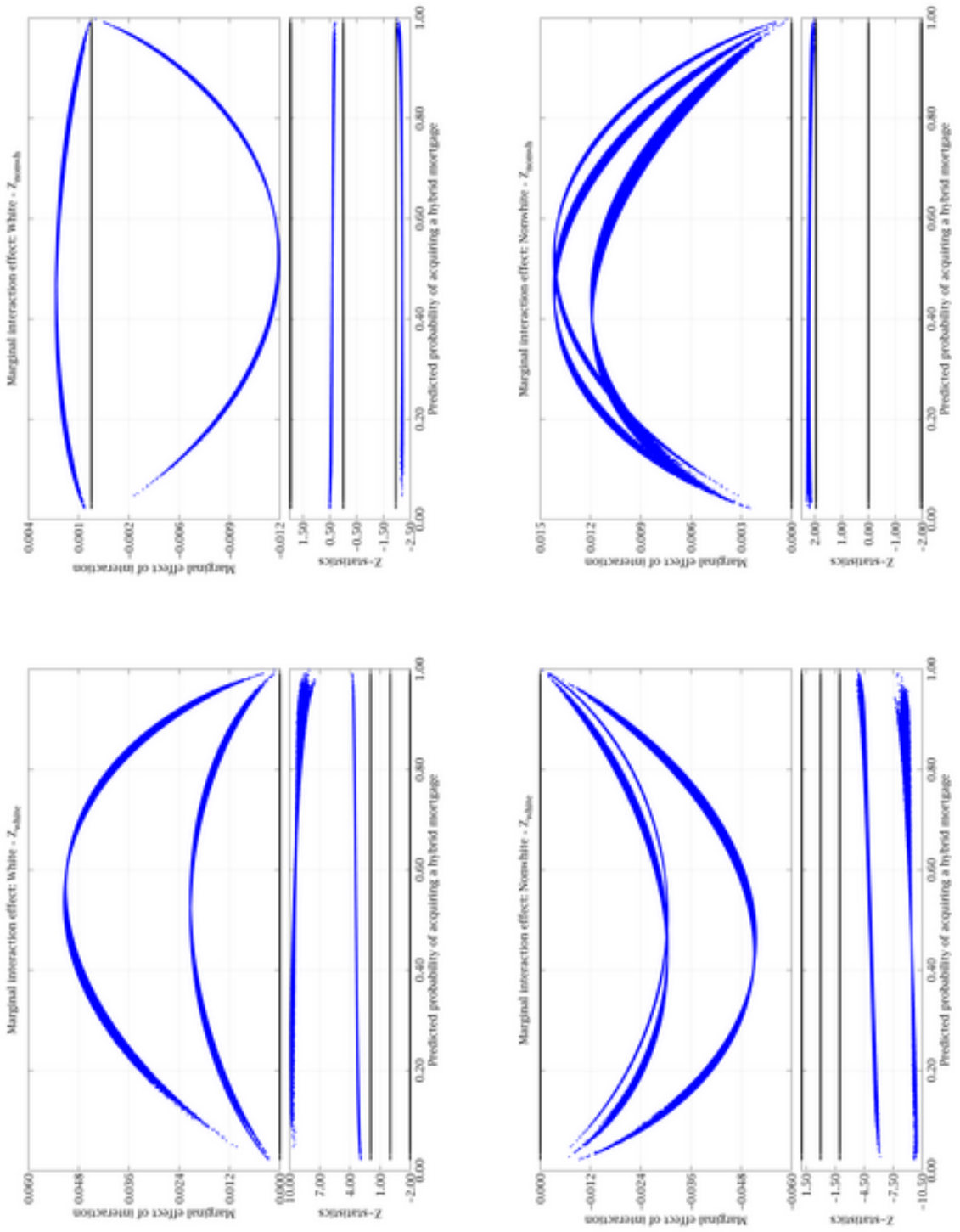

Figure 4: Marginal Effects of Interaction. Hispanic v. Black. Reduced form results with tract adoption